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INVESTIGATION OF STABILITY PARAMETERS ON SURFACE RESPONSE DURING TURNING OPERATION OF MILD STEEL

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CERTIFICATE OF APPROVAL

Certified that the project dissertation entitled

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Finally, we would like to show our deepest respect to our parents, family, friends and all those who showed patience and tenacity with us to finish with success.

Dedicated to My Dear Parents Who Supported Me to Fly When I was An Eaglet

ABSTRACT

This thesis presents an experimental investigation with the main focus of determining the effect of cutting parameters as well as the tool construction on the surface roughness, chip size and structure, tool tip temperature and the chip morphology with variation in the tool over-hang length. Machining experiments were carried out on a conventional lathe machine using carbide cutting insert coated with TiC and two forms of cutting tools made of AISI 5140 steel. Three levels for over-hang length was selected as the cutting variable viz. 20 to 70 mm, depth of cut, feed rate and the machine rpm were kept constant. Through graphical and observational techniques, it was observed and concluded that the over-hang length had a significant effect on the surface roughness, the tool tip temperature as well as other parameters kept in check. These experiments led to the establishment of an optimum over-hang length value with promising result of surface finish quality and with little tool wear and negligible internal stress caused by overheating during cutting.

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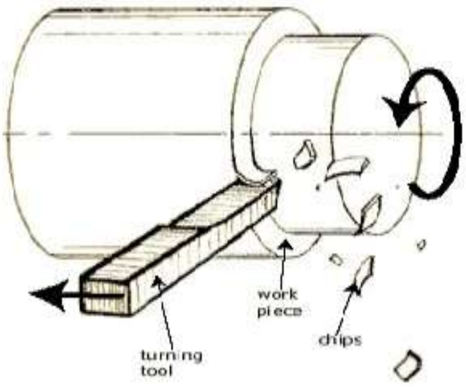
CHAPTER 1

INTRODUCTION

1.1 BASICS OF TURNING AND SURFACE ROUGHNESS

Turning is a metal cutting process used for the generation of cylindrical surfaces. Typically the workpiece is rotated on a spindle and the tool is fed into it radially, axially or both ways simultaneously to give the required surface. The term turning, in the general sense, refers to the generation of any cylindrical surface with a single point tool. More specifically, it is often applied just to the generation of external cylindrical surfaces oriented primarily parallel to the workpiece axis. In turning, the direction of the feeding motion is predominantly axial with respect to the machine spindle.



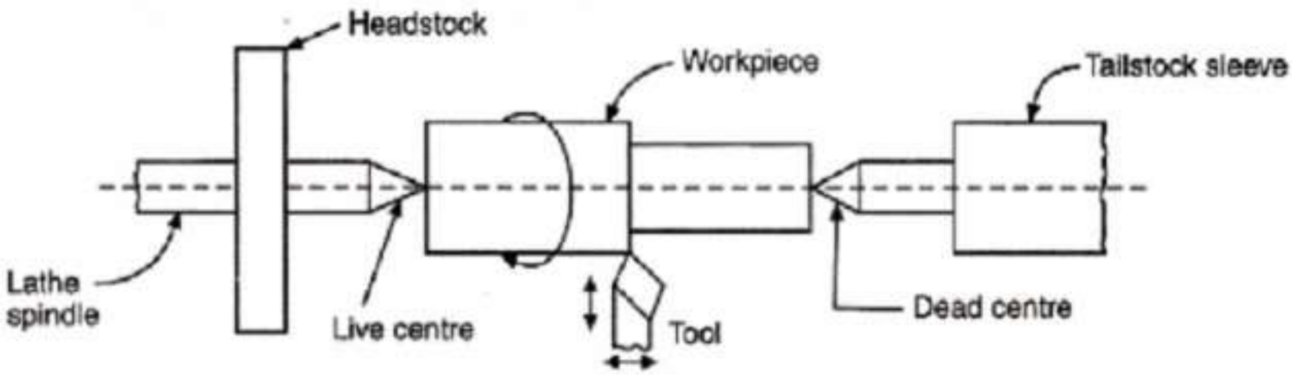
1Fig 1.1a of turning operation

Surface roughness, often shortened to roughness, is a component of surface texture. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion

1.2 PRINCIPLE AND SCHEMATIC OF THE MACHINE.

A lathe is a powered mechanical device in which the work is held and rotated against a suitable cutting tool for producing cylindrical forms in the metal, wood or any other suitable machinable material.

1.2.1 PRINCIPLE OF WORKING



2Fig 1.2.1a.working principle of the turning machine

The principle of lathe machine is that it holds the work between two strong supports called as centers or in a check or face plate which revolves. The chuck or the center is mounted on the main spindle of the machine. The cutting tool is rigidly supported in a tool port and it is fed against the rotating job. The job rotates in its axis and the tool is moved either parallel or to an inclination with its axis as such a cylindrical or tapered surface is produced.

1.2.2 MACHINE PRINCIPLE PARTS

i) Bed

The bed is the function of the lathe. It is supported on board box columns and is made of cast iron. It consists of two heavy metal slides running lengthwise with ways. Units which are mounted on the bed are the head-stock, the tail-stock and the carriage. Lathe bed is made of high grade special cast iron having high vibration damping qualities. It is secured rigidly over cabinet leg and leg. In its use care should be taken to avoid formation of scratches, nicks and dents by falling tools. It should be lubricated regularly.

Gap beds Some beds have a gap just adjacent to the front of the head stock. It is gap beds. This type of bed can accommodate jobs which are bigger in diameter, but it is true for jobs of shorter length only

ii) Head stock:

It supports the main spindle in the bearings and aligns it properly. It also houses necessary transmission mechanism with speed changing levers to obtain different speeds. Cone pulleys or gears could be used to change the speed of spindle. Holding devices which are mounted on the headstock spindle.

iii) Main spindle

It is a hollow cylindrical shaft and long cylindrical jobs can pass through the main spindle. The spin end facing the tail-stock is called the spindle nose. The spindle nose has a mores taper hole (self-locking taper) and threads on outside. The mores taper is used to accommodate center or collet chuck or threaded portion of chuck.

iv) Tail-stock

It is a movable part located opposite to head-stock on the ways of the bed. It is capable of sliding along the bed maintaining its alignment with head-stock. On medium size and smaller lathe it is moved along the bed manually, whereas in heavier lathes it is moved by hand wheel through a pinion that meshes with rack provided in front of lathe bed. It is used for four purposes:

a. To support free end during machining.

b. To hold tool for performing operations like drilling, reaming, tapping etc.

c. To center the job and the tool before any lathe operations.

d. To help in the operation of taper turning by tail stock set over method.

v) Carriage

It is located between head-stock and tail-stock. It can slide along bed guide ways and be locked at any position by tightening the carriage lock screws. It consist of following five main parts

a. apron

It is fastened to saddle. It contains gears and clutches for transmitting motions from feed rod and hand wheel to the carriage. Also split nut which engages with the lead screws during threading. The clutch mechanism is used for transmitting motion from feed rod whereas the split nut along with the lead screw moves the carriage during thread cutting.

b. saddle

It is made up of H-shaped casting. It aids saddle to slide on bed guide ways by operating hand wheel.

c. compound rest

It supports the tool post and cutting tool in its various positions. It may be swiveled on the cross-slide to any angle in the horizontal plane.

d. cross-slide

It is provided with a female dovetail one side and assembled on top of saddle having a male dovetail.

e. tool post

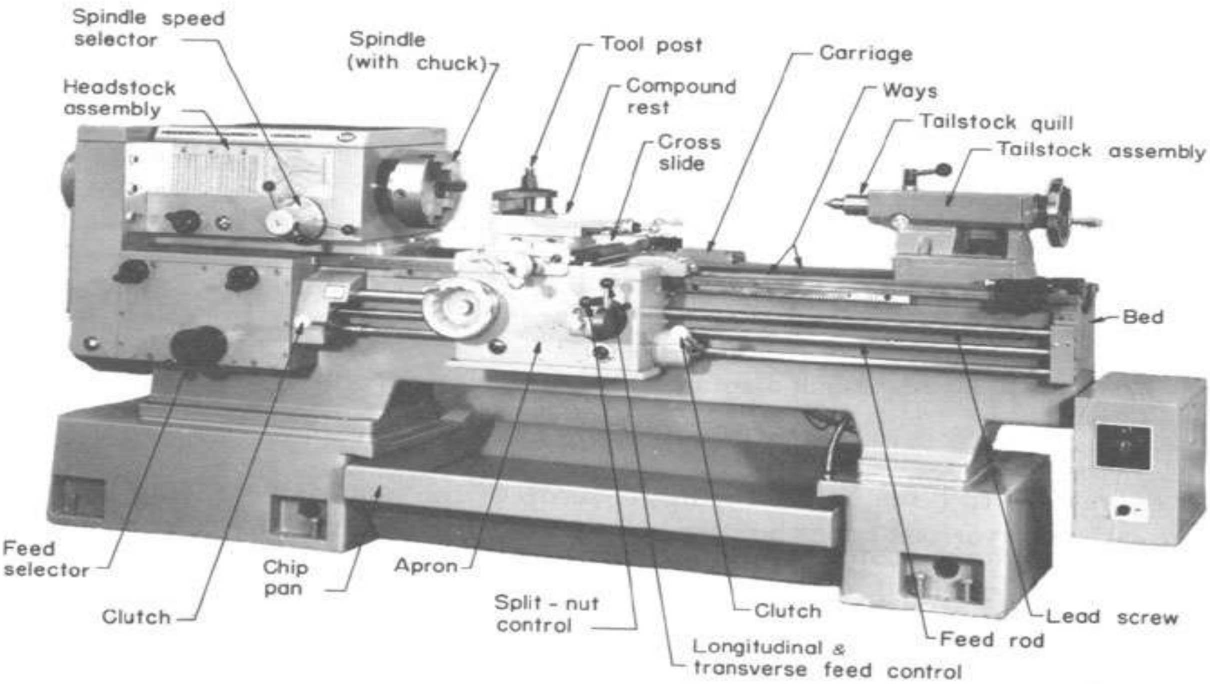
It is used to hold various tool holders and tools. Three types of tool post commonly used are:

- Ring and rocker tool post
- Square head tool post
- Quick change tool post

(vi) Legs

They are supports which carry entire load of the machine. Legs are casted and it is placed on the floor of the shop of foundation by grouting. The left leg acts as housing for the motor, the pulleys and the counter shaft at the same time the right leg acts as a housing of coolant tank, pump and the connecting pipes.

1.2.3 MACHINE SCHEMATIC



3Fig 1.2.3a working principle of the turning machine

1.3 OBJECTIVE OF THE PROJECT

In the recent years, industrialization has led to rapid innovations and advancement in technology both in the industrial and the architectural sectors. In this study we will look at one of the ways by which the contributions of the turning processes of the lathe machine to this era of development can be improved. These categories of machines are considered to be the oldest machine tools, and can be of four different types such as straight turning, taper turning, profiling or external grooving. Those types of turning processes can produce various shapes of materials such as straight, conical, curved, or grooved workpiece. In general, turning uses simple single-point cutting tools. Each group of workpiece materials has an optimum set of tools angles which have been developed through the years.

The main purpose of this study is to investigate the effect of tool overhang length on the machined surfaces. It is no doubt that the optimum tool performance depends to an extend on how far it extends from the tool post, relative to the spindle rpm and other parameters such as the feed, depth of cut as well as the ambient conditions. Our study basically sets out to determine what overhang length is best during external turning, by studying the temperature response of the tool tip-chip zone, the chip structure of the produced chips, the surface roughness of the job piece and the grain structures against each over-hang length. Establishing an optimum value for the overhang will be an excellent breakthrough in the field of manufacturing and production alike. It will equally lead to economical operations since the acoustic vibrations responsible for tool wear will be reduced if not completely eliminated.

1.4 ORGANIZATION

The organization of our report is done based on the goal and objectives of the overall project. We will divide out report into six main chapters, in which we will cover

1. The introduction,
2. The literature review,
3. The experimental set up,
4. The experimental results
5. Recommendation for further studies.
6. And the references.

Under each respective topic, we will look at the introduction and the body for that particular topic, while covering all the necessary grounds as far as the study is concern.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION.

In this section, we will present the literature connected with the previous works. We will equally include the highlights about the latest developments in the areas related to the present work. The main features of hard machining such as the formation of chips and the cutting tools used are presented. It also covers an account of the experimental design, its optimization techniques and the techniques used for enhancing the cutting performance.

2.2 HARD MACHINING.

Components made of steel that require high hardness are usually made by rough turning in the soft state, followed by heat treatment to the required hardness and then grounded to the final dimensions using precision grinders. According to Koenig in 1984, this lengthy process can be shortened by machining and grinding to the desired dimensions in the hardened state. As such, operations such as rough machining and final grinding are eliminated and the raw material is supplied as hardened steel. The functional characteristic of the machined parts is a function of the fine finishing process, which signifies the last step in the chain process, according to Tonshoff in 1993.

Hard materials include hardened steel, high-speed steel, heat treatable steel, tool steel, bearing steel and chilled/white cast irons. All these materials have a wide range of applications in the automotive industries and their allied.

2.3.1 IMPORTANCE OF HARD MACHINING.

Hard machining has a number of benefits; some of these are listed below.

i. Easy to adapt to complex contours in machining parts.
ii. Has a high rate of metal removal.
iii. Rapid change-overs between the component types.
iv. No cutting fluid required in most cases.
v. In a single step, several operations can be performed.

2.3.2 DISADVANTAGES OF HARD MACHINING.

Despite the merits of hard machining in manufacturing, there are still some limitations and draw backs to this mode of manufacturing. Some of these limitations are;

The cost per unit tool is quite high in hard machining when compared to grinding.

This process requires rigid cutting systems and superior cutting tools like CBN/ceramic tools as established by Einesblatter and Klocke in 1997. The more rigid the machine, the more accurate it will be and the more productive.

There is deterioration of the surface finish of the machined parts with the tool wear even as far as the tool life limit.

Hard machining requires tools made from materials with high internal damping capacity. This reduces the negative effects of vibrations on the surface finish, as stated by Rahman, Ohama and Fowler in 1987, 1997 and 1999 respectively.

2.4 HARD DRY MACHINING

Hard dry machining is more or less the same as the hard machining described above, the main difference is in hard dry machining, there is no coolant fluid used to cool the tool tip and the work piece whereas in the previous machining process, a coolant may or may not be used. According to past related studies, this means of machining had been chosen in order to eliminate environmental effects as much as possible, especially when temperature measurement is of great important.

Considering the expensive nature of the cutting fluids and taxes paid when stricter environmental laws are enforced. As such, the choice of elimination of the cutting fluids, if necessary, can be quite economical during metal cutting. It also has an added advantage of cleaner pars, low waste, reduced production cost, and reduced cost of chip recycling. According to Klocke and Einesblatter, 1997-99, dry machining operations are now of great importance and actually tend to be an environmentally friendly means of manufacturing. Also according to Avila and Abrao (2001), during hard machining, concentration of heat in the cutting zone reduces the shear strength of the job piece, resulting in lower cutting forces. However according to Dhar (2007), in reality, dry machining operations are many times less effective when higher machining efficiency, better surface finish and severer cutting conditions are required.

Total elimination of the cutting fluids that act as coolant and lubricant calls forth the use of ultra-hard cutting tools as well as extremely rigid machinery since machines and tools made for machining with metals working fluids cannot be readily adapted for dry cutting, which will again add to the cost of machining as suggested by Klocke and Einesblatter,(1997). Hence, new and more powerful machines must be purchased and special tooling is often needed to withstand the high temperatures generated in dry cutting. The quality of machined parts may be affected significantly as the properties of the machined surface are significantly altered by dry machining in terms of its metallurgical properties and residual machining stresses. High cutting forces and temperatures in dry machining may cause the distortion of parts during machining. Moreover, parts are often rather hot after dry machining to their handling, inspection gauging etc., may present a number of problems.

2.6 VARIATION OF CHIP SHAPE WITH CHANGE IN OVER-HANG LENGTH

From the nature of the chips produced, one can tell exactly how effective the machining process is. Controlling chip breaking is very important in automated manufacturing processes to ensure reliable and safe machining. The chip shape and size produced depends entirely on the machining conditions and the tool geometry. The chip formed is very unstable and varies with ease even when the cutting conditions are kept the same for the experiments. This was also observed by Nakayama and the colleague Ogawa in 1978, this observation is as a result of variation of coefficient of friction between the tool and the chip, variation of the tool tip temperature and the variation in tool geometry due to progression in tool wear and irregularities in the density of the work material that causes non-uniformity. Based on the work of Nakayama and the partner, the following results were obtained.

i. In the process of hard machining, the saw toothed chip is formed due to fracture of the work piece. This means that the crack initiates at the job piece free surface when the work material attains the limiting shear strain. Therefore one can conveniently say fractures govern chip formation process, determining the shape and size of the chip.

ii. Despite the fact that "segmental chips" formed in hard materials due to adiabatic shear has a similar cross-section to the saw –toothed chip formed in materials difficult to machine, these chip types are not the same however because they are formed by different mechanisms.

iii. The shear angle is very small compared to the traditional machining. It significantly increases with the hardness of the work piece and somewhat depends on the tool rake angle.

The periodic crack theory assumes that periodic shear cracks first develop near the surface of the job piece and proceed downward along the shear plane towards the tool tip. Following crack formation, bands of concentrated shear may or may not then develop (Shaw and Vyas, 1998). Elbestawi (1996) also developed a chip formation model, in which it starts with initiation of a crack at the free surface layer energy/strain energy density criterion. According to Davies (1996) chip morphology is independent of work material microscopic structure but is a function of tool wear during finishing turning of hardened steel.

The nature of chip formation in hard machining is quite different from that in conventional machining. In machining of more ductile materials, chip formation is accompanied closely by great plastic deformations around the shear zone. The formation of the saw-toothed chips for instant is one of the primary features of the machining of hardened steels with geometrically defined cutting tools. Severe failures within the primary shear zone during saw-tooth chip formation are often attributed to both cyclic crack initiation and propagation or to the occurrence of a thermo-plastic instability, according to Barry and Byne (2002) and Davies (1997).

Furthermore, according to Childs (1972), reducing the coefficient of friction by adding a lubricating fluid causes the chip to become thinner and curled. Evidently it's no doubt here that when matter is heated it expands and contracts when cooled. We never however observed this phenomenon in our study since we were limited to dry hard machining. The nature of contact between chip and tool rake face has a major influence on the direction of chip flow as stated by Ackroyd (2003).

2.6 VARIATION OF SURFACE ROUGHNESS WITH CHANGE IN TOOL OVER-HANG LENGTH.

In the turning operations, vibration is a regular problem, and ultimately has affects the result of the machining process as a whole and in particular the surface finish. Tool life is also affected by vibrations. Extreme acoustic noise in the working environment frequently caused a dynamic motion between the cutting tool and the work piece. In all cutting operations like turning, boring and milling vibrations are induced due to deformation of the work piece. In the turning process, the importance of machining parameter choice is increased, as it controls the surface quality required.

Tool overhang is a cutting tool parameter that has not been investigated in as much detail as some of the better known ones. It is appropriate to keep the tool overhang as short as possible; however, a longer tool overhang may be required depending on the geometry of the work piece and when using the hole turning process in particular.

In this study, we investigate the effects of changes in the tool overhang in the external turning process on the surface quality of the work piece. For this purpose, we used work pieces of Mild Steel material each of diameter 32mm; and the surface roughness of the work piece were determined through experiments using constant cutting speed and feed rates with same depth of cuts (DOCs) and different tool overhangs. We observed that the effect of the DOC on the surface roughness is negligible, but tool overhang is more important. The deflection of the cutting tool increases with tool overhang.

Machining processes are manufacturing methods for ensuring processing quality, usually within relatively short periods and at low cost. Several machining parameters, such as cutting speed, feed rate, work piece material, and cutting tool geometry have significant effects on the process quality. Many researchers have studied the impact of these factors. The cutting tool overhang affects the surface quality, especially during the turning process, but this has not been reviewed much. Based on applications and theoretical approaches, it is known that cutting tools need to be clamped as short as possible to achieve the desired surface quality of the work piece. For the internal turning method in particular, the cutting tool should be attached with the proper length, not with the shortest distance. This situation may also be the case for external turning processes, depending on the work piece geometry. In this study, we investigate the effects of cutting tool overhang on both the surface quality in external turning processes. Because the tool holder is subject to bending and buckling depend on effect point of the cutting force (tangential force), cutting tool displaced. This situation has negative effects on the surface quality.

Metal cutting is one of the most significant manufacturing processes, according to (Chen and Smith, 1997) in the field of material removal. Black (1979) in his study also defines metal cutting as the removal of metal from a work piece in the form of chips in order to obtain a finished product with desired attributes of size, shape, and surface roughness among other qualities. Drilling, sawing, turning, and milling are some of the processes used to remove material to produce specific products of high quality.

The theory of metal cutting is very well established. However, some aspects have gone through revision when the experimental results showed the new parameters involved in metal cutting. Many new alloys have also been developed to react to today applications. As a result, there will be always a need for continuous research and improvement to tool materials, cutting conditions and parameters to optimize the output. Finnie (1956) in his own study first reported that the earliest documented works in metal cutting was done by Cocquilhat in 1851. Taylor in 1906 was investigating the effect of tool material during cutting after which he formulated the famous Taylors tool life equation ***(VTn = C)*** which is still valid until now and was used by researchers as a basis to show the performance of a given tool. The mechanics of metal cutting are very complex. Turning is used to produce rotational, typically axis symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed. The work piece rotates in the lathe, with a certain spindle speed (n), at a certain number of revolutions per minute. In relation to the diameter of the work piece, at the point it is being machined, this will give rise to a cutting speed, or surface speed (Vc) in m/min.

This is the speed at which the cutting edge machines the surface of the work piece and it is the speed at which the periphery of the cut diameter passes the cutting edge.

2.7 RESULTS AND DISCUSSION.

According to the reports of the previous researchers in the similar fields of research, the following results were obtained. Three major issues produced surface finish integrity as well as the tool performance. These will relate all research area in metal cutting. The influence of cutting condition will be discussed when evaluating the surface roughness. The results obtained from the experiments test using different cutting tool length parameter diameter when turning Aluminum showed that surface roughness were produced differently. Generally, when a short tool over-hang length is used, the surface roughness is always good, ranging from 0.75 to 3.41 µm. Within this range of surface roughness, the best result is obtained at a cutting speed (S) of 315 m/min at low feed rate 0.0415 mm/rev. From the result, it can be concluded that using a short tool length always provide good surface roughness in a turning boring operation, no matter what cutting parameter or type of boring bar used. In fact, only a slight improvement on surface roughness can be achieved when setting the cutting speed (S), feed rate (f) or depth of cut (doc) to the values specified above.
At this point, it can be observed that turning operation using a long tool length may set excessive vibrations that decrease the surface quality.

CHAPTER 3

EXPERIMENTAL SET-UP

3.1 INTRODUCTION.

In this study, we selected the tool overhang as variable experimental parameter, while keeping the depth of cut, the cutting speed and feed constant. The surface roughness of the work piece and the tool tip temperature were measure and the chip size & morphology studied and analyzed. We carried out our experimental studies using a conventional lathe. Our cutting tool was a P10 grade-coated sintered carbide and HSS inserts (the standard DNMG150608 and PDJNR2525 type tool holders). The work pieces used in the experiments were 32 mm in diameter. Our choice for this diameter was based on the fact that the literature survey provided information about selection of the work piece diameter, and these values lay in the range 23–100 mm. In this study, we selected work pieces of materials and diameters that are widely used in industrial applications. We used a tailstock to prevent deflection of slender work pieces during machining operations while maintaining the job piece length at 200mm to establish a more rigid setup. As the work piece material, we selected the quite commonly preferred steel in the manufacturing industry, AISI 1050. This material contains 0.48–0.55% C, 0.17% Mn, and 0.69% Si, and has a hardness value of between 175 and 207 HV, depending on the applied heat treatment. The tool overhang lengths were 20, 30, 40, 50, 60 and 70 mm. For the DOC we selected was 1.0 mm. The cutting speed and feed rate were selected as 530 rpm and 0.95 mm/rev, respectively. The external turning processes were carried out using the anticipated parameters. The processes can be seen *Fig 3.4 (b)*

3.2 METHODOLOGY

Turning is a kind of machining process in which a cutting tool, typically a non-rotary tool bit, describes a helical tool path by moving more or less linearly(assuming no vigorous vibrations) while the workpiece rotates. Motion of tool axis may be literally a straight line, or may be along some set of curves or angles, but they are essentially linear in the sense that they are never rotated about a given axis. Usually the term "turning" is reserved for the generation of external surfaces by this cutting action, which is basically the point of focus of our study, whereas this same essential cutting action when applied to internal surfaces (that is, holes, of one kind or another) is called "boring". Thus the phrase "turning and boring" categorizes the larger family of (essentially similar) processes. The cutting of faces on the workpiece (that is, surfaces perpendicular to its rotating axis), whether with a turning or boring tool, is called "facing", and may be lumped into either category as a subset. The figure below shows the examples of external turning operations.

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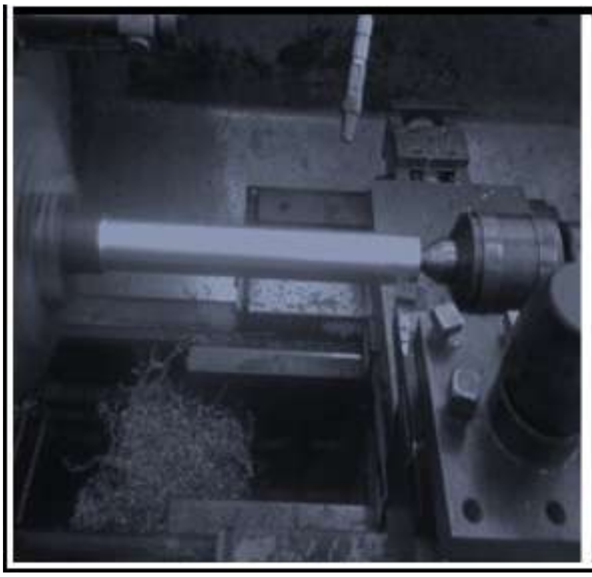
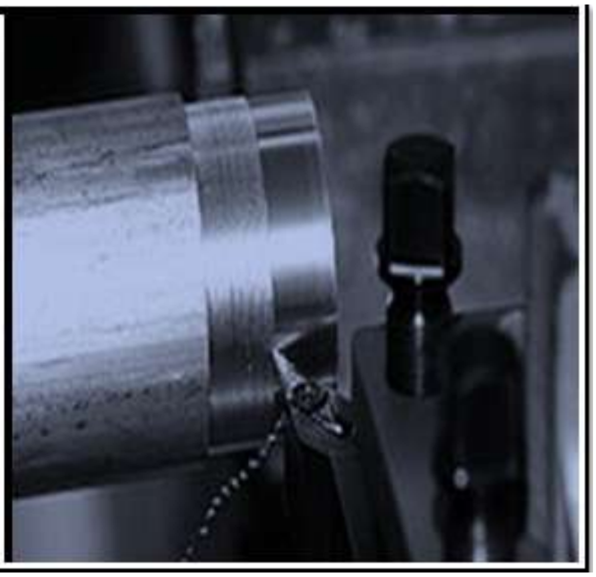


4Fig 3.1a Rough turning



5Fig 3.1b Finish turning.

Turning operations are either done manually, in a traditional form of lathe, which requires continuous regular supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with many other types of machining besides turning.)

When turning, a piece of relatively rigid material (such as steel) is rotated and a cutting tool is traversed along x, y and z axes of motion to produce precise diameters and depths. Turning operations could be either on the outside of the cylinder or on the inside (boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although since the advent of CNC it has become unusual to use non-computerized tool path control for this purpose.

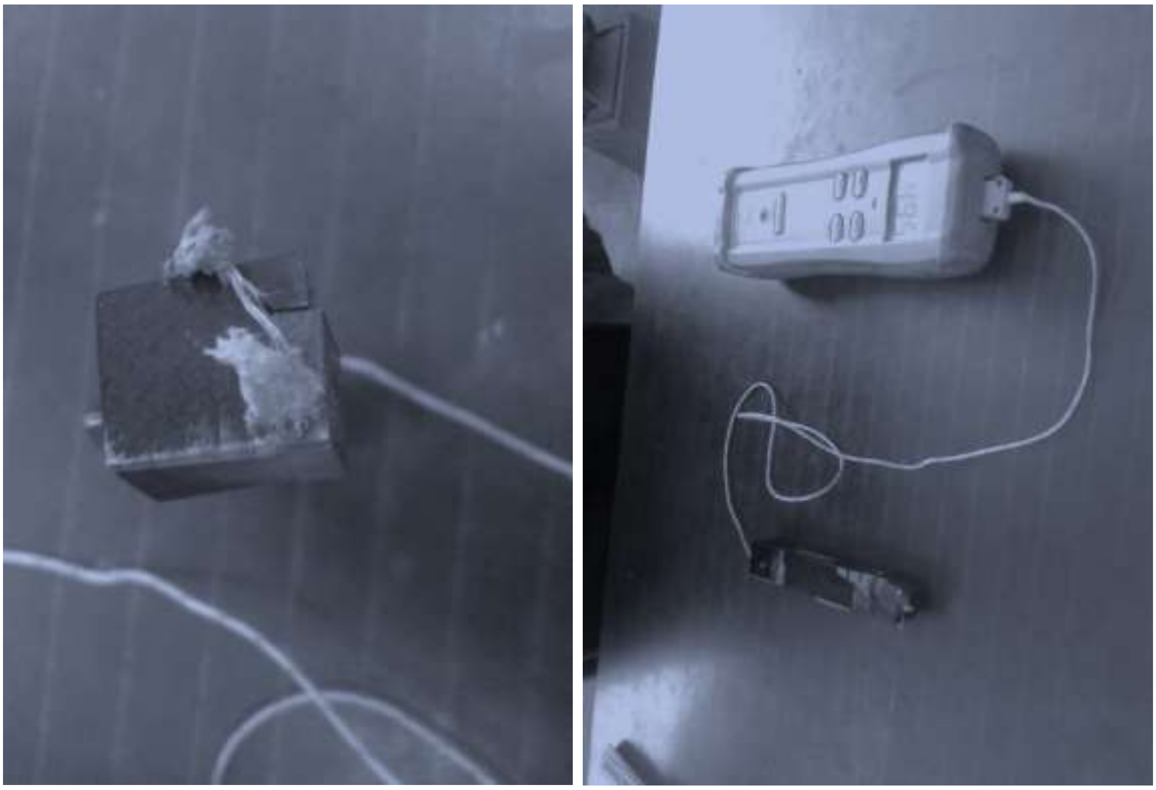
The bits of waste metal from turning operations are known as chips (North America), or swarf (Britain). Also referred to as turnings in some regions.

3.2.1 MEASUREMENT OF TOOL TIP TEMPERATURE.

In our study, measuring the tool tip temperature was a little tricky. Among the various ways of measuring the tool tip temperature, we selected the embedded thermocouple method. The main reason for our choice of this method was because of its simplicity in both designing and implementing. With the help of fevicol super glue, we attached the joined tip of the thermocouple slightly below the nose of the cutting tool to allow machining thermal activity detection. This method however convenient and adaptable had a few drawbacks such as;

i. It needed constant checking to ensure firm contact of the thermocouple wires.
ii. Wires used could be dangerous since it can get tangled in the rotating job piece.
iii. Only one thermal pool allows no opportunity for temperature comparison to a chosen reference.
iv. It wasted a lot of time setting up the apparatus.

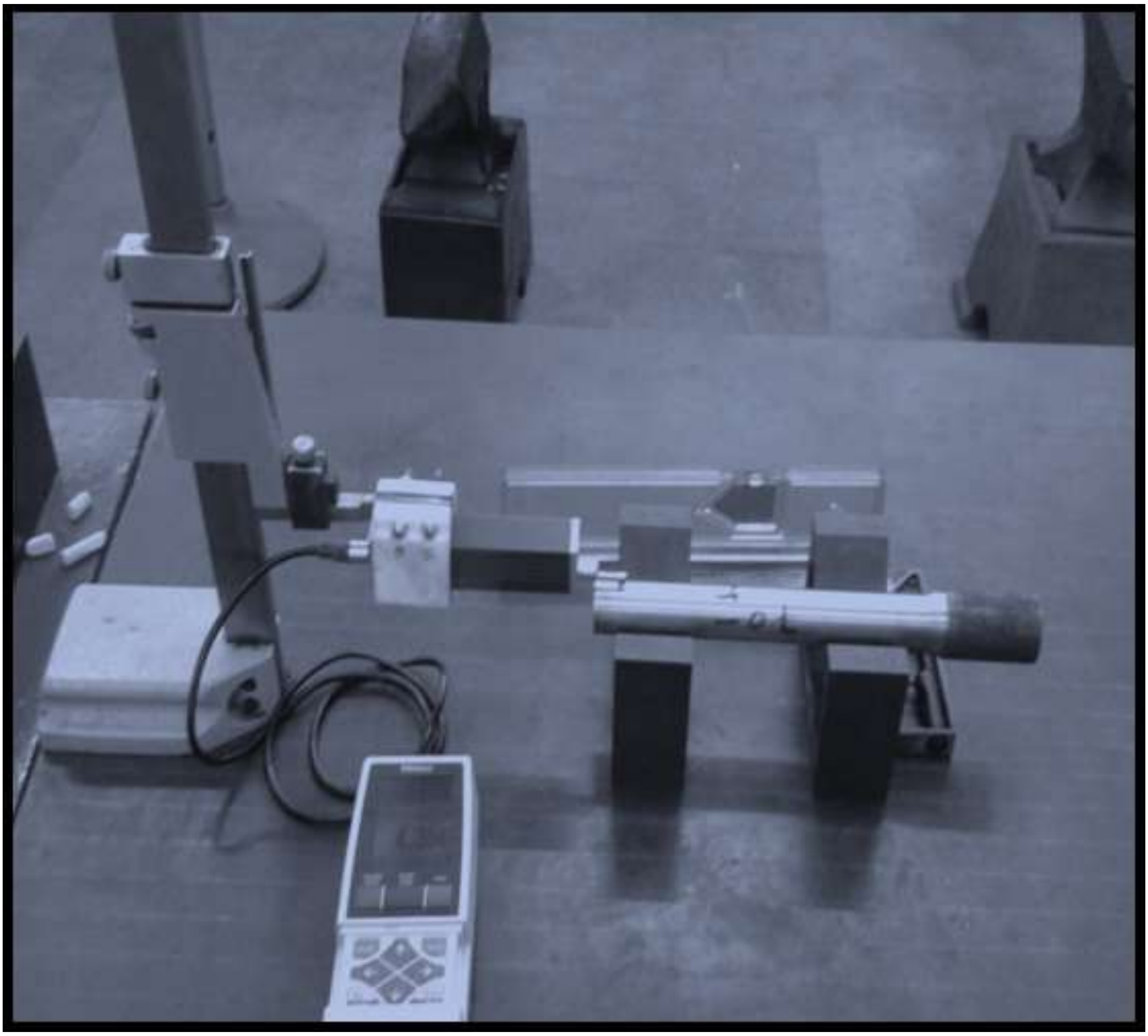
The figure below shows the connection circuit we manually made in the mechanical workshop. The experimental results will be discussed in chapter 4



6Fig 3.2.1a Measurement of the tool tip temperature.

3.2.2 MEASUREMENT OF THE SURFACE ROUGHNESS.

Surface roughness which is the direct implication of the degree to which the job was well done was relative easy to measure. We used a digital surface roughness tester which instantly gave the result both in numerical and graphical forms. The tester had a sharp pin (stylus) which it used to Travers the surface of the job piece under examination. Based on the emf generated which is proportional to the degree of roughness of the surface, a graph is generated using a micro oscilloscope built in the tester. The numeral value of the surface roughness then indicated on the screen. The figure below shows the apparatus used for measuring the surface roughness.



7Fig 3.2.2a Measurement of the surface roughness.

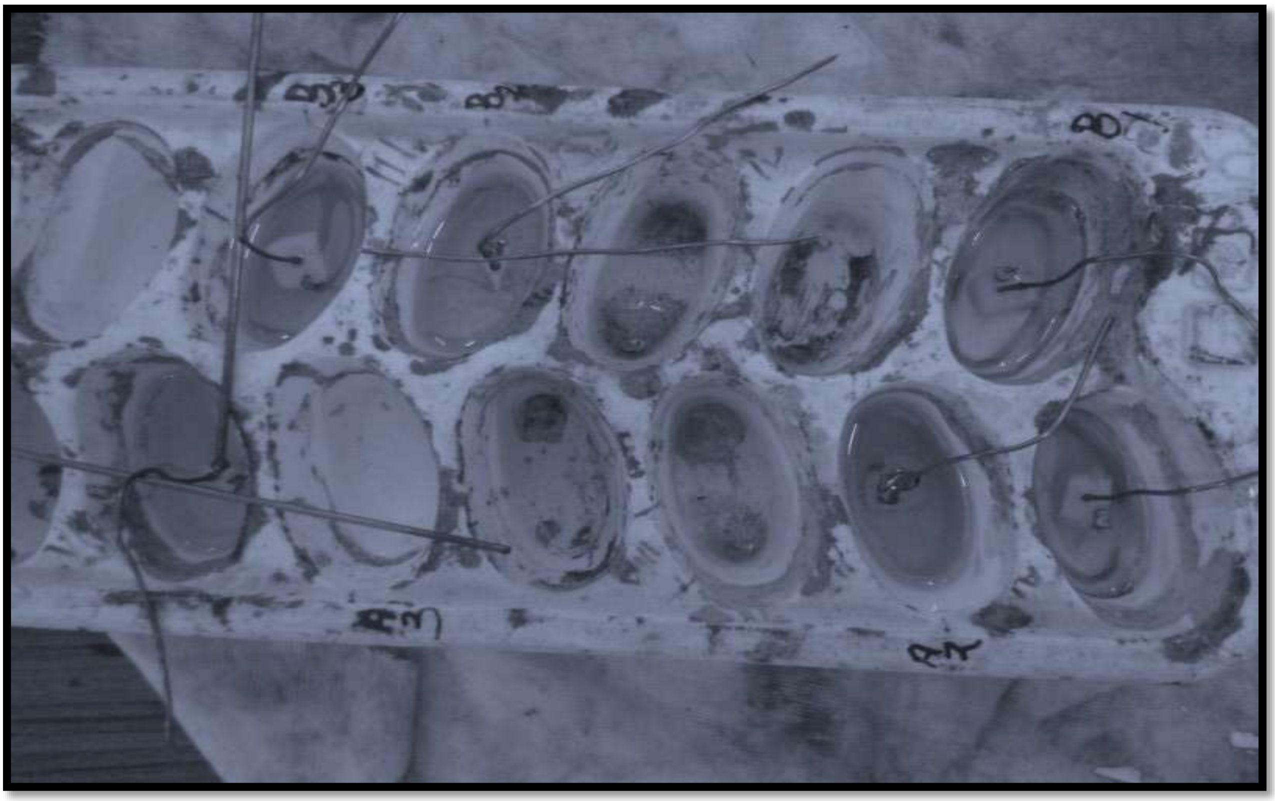
The only drawback to this means of measurement is that there is no scope for measurement of extremely rough surfaces machined in the workshop. It is advantageous in that it is complex and requires less practice to manipulate.

Our experimental results will be discoursed in chapter three

3.2.3 CHIP GRINDING AND MORPHOLOGY.

The sizes of the chip were quite small to handle during grinding and microscopy, so with the help of glassy tablets in which the chips were embedded in a particular plane, we were able to grind and observe the chip morphology with ease.

The glassy material was made from a resin and a hardener, in the ratio of $15ml^3$ resin to $3ml^3$ of hardener solution. When the hardener is added to the resin and stared for a while, it is allowed to settle while the chip mounted on a tiny cube of bathing soap is embedded while in the molten state with the help of a copper wire as the handle as shown on the figure below.



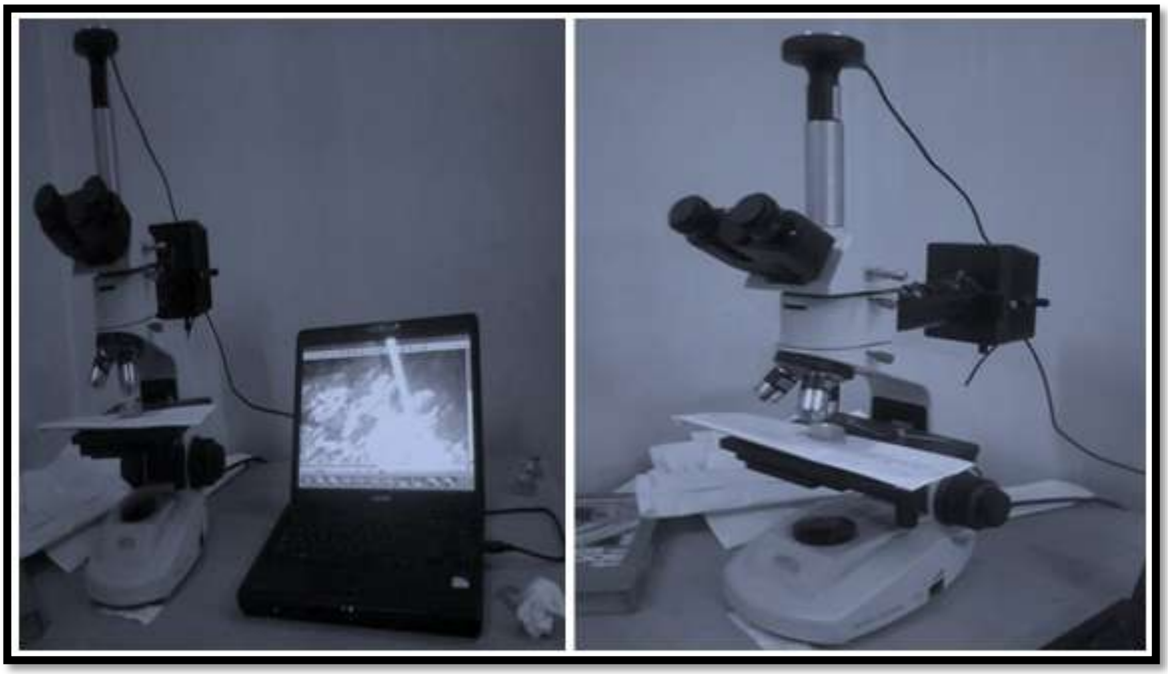
8Fig 3.2.3a Measurement preparing the chip for grinding.

(*The transparent medium is molten and hardens after a few hours; the white looking substance is a bathing soap piece to ease attachment to the copper wire as shown*)

After a few hours, the prepared chips were grounded using a fine grade emery paper and polished on fine polishing machine. The grounded chips are then rinsed in nitol solution or any other alcohol to remove any particles on the grounded surface. The chip was removed from the nitol dried in air and mounted immediately to avoid the formation of rust on the grounded surface. The figures below show the grounded and ready chips. The results will be discoursed later in chapter 3

9Fig.3.2.3a chips grounded and ready to be observed. The bottle contains and alcohol called nitol used to wash the grounded chips in a small plastic basin as shown.

The figure below shows the metallurgical microscope we used



10Fig 3.2.3b Observation of the chip grain structure using a high power microscope with an embedded camera for snapping the chip structure.

3.2.4 CHIP SHAPE AND SIZE

For each of the job pieces, different overhang lengths were used, while making sure that the job diameter was the same for all the job pieces. This was done by ensuring tight control on the depth of cut of the job so that the reduction in the diameter was exactly the same for all the job pieces. Here, no special tool was used to examine the chip shape and size. It was observed and the results recorded accordingly. *See chapter 4*

3.2.5 MEASURING SURFACE ROUGHNESS.

A Mitutoyo Surf test SJ-400 Portable Surface Roughness Tester measuring instrument show in Figure 3.2 was used to process the measured profile data. The SJ-400 is capable of evaluating surface textures including waviness with the variety of parameters according to various digitally/graphically on the touch panel and output to built-in printer. The stylus of the SJ-400 detector unit traces the minute irregularities of the work piece surface. Surface roughness is determined from the vertical stylus displacement produced during the detector traversing over the surface irregularities and the measuring setup shows in figure 3.1 below. The Lathe Tool Dynamometer has been designed so that it can be directly fixed on to the tool post using the hole provided on the dynamometer. The dynamometer can measure 3 forces in mutually perpendicular

11Fig 3.2.5a Apparatus for measuring the surface roughness

Directions, i.e. horizontal, vertical and thrust, and is provided with 3 connector sockets. Instrument comprises of three independent digital display calibrated to display force directly using three component tool dynamometer. This instrument comprises independent DC excitation supply for feeding strain gauge bridges, signal processing system to process and compute respective force value for direct independent display in kgf units. Instrument operates on 230v, 50 c/s

AC mains. Size – 150x475x270 mm nominal. Cutting condition need to setup in this experiment, to make sure all the experiment run follow according the data given. A fractional factorial is selected so that all intersection between the independent variables could be investigated. The dependent variable is the resulting first 58 cut surface roughness. The level was selected to cover the normal cutting operation.

3.2.6 MEASURING TOOL TIP TEMPERATURE

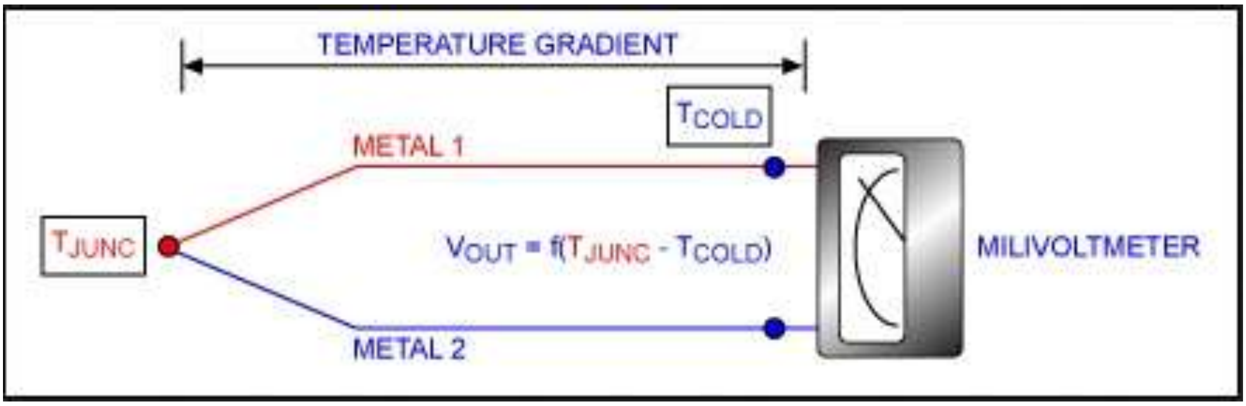
There are number of methods for measuring the chip tool interface temperature; Tool work thermocouple, Radiation pyrometers, embedded thermocouples, temperature sensitive paints and indirect calorimetric technique. Of all these methods, the tool work thermocouple technique is the most widely used technique for the measurement of the average chip tool interface temperature; however, we used the embedded method due to its convenience and adaptability. The other methods suffer from various disadvantages such as slow response, indirectness, and complications in measurement.

3.2.7 THERMOCOUPLE

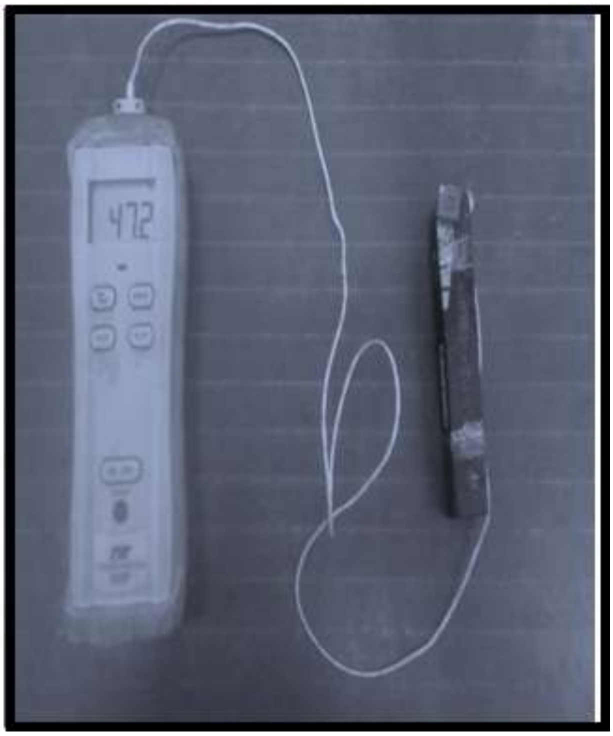
A thermocouple is a temperature sensor based on the principle that a voltage is produced when two dissimilar metals. The junction produces a voltage in proportion to the difference in temperature between the measuring junction and the reference junction.

An experimental setup designed, fabricated and calibrated in mechanical engineering workshop to measure the temperature on cutting tool and work piece junction during metal cutting on precision lathe as shown in Figure2. This method of tool temperature measurement employs the tool (carbide tool) and the work material

(Alloy steel) as the two elements of a thermocouple. The thermoelectric emf generated between the tool and work piece during metal cutting is measured using a sensitive mill voltmeter. The hot junction is the contact area at the cutting edge.



12Fig 3.2.7a simplified circuit of a thermocouple



13 Fig 3.2.7b manually made circuit in the lab lead wire from the tool

14Fig 3.2.7c Photo showing the thermocouple during machining

3.2.8 CALIBRATING THE TOOL OVER-HANG ON THE TOO

In our study, we used an ordinary medical plaster to make the calibration scale. We chose this material because of its ability to stick to the tool even at high temperatures when the machine is running. It had the advantage of serving time and mistakes since it required us to dismount and mount the tool on the tool post after changing the tool overhang as measured earlier with the plaster. The calibration means is shown in the figure below.

15Fig 3.2.8a The cutting tool showing the calibration scale of the overhang-length manually done in the machine workshop.

CHAPTER 4

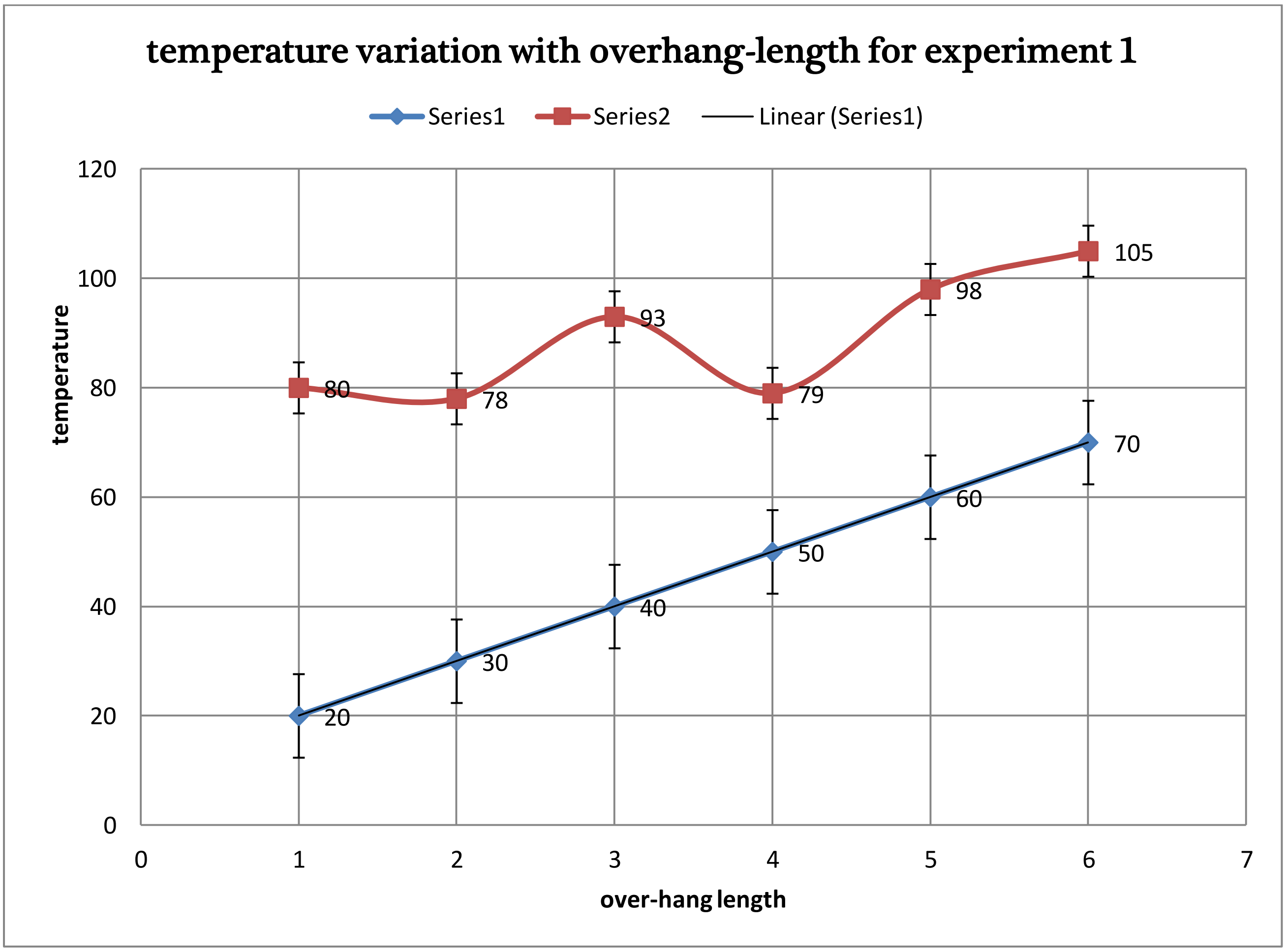
RESULTS AND DISCUSSION

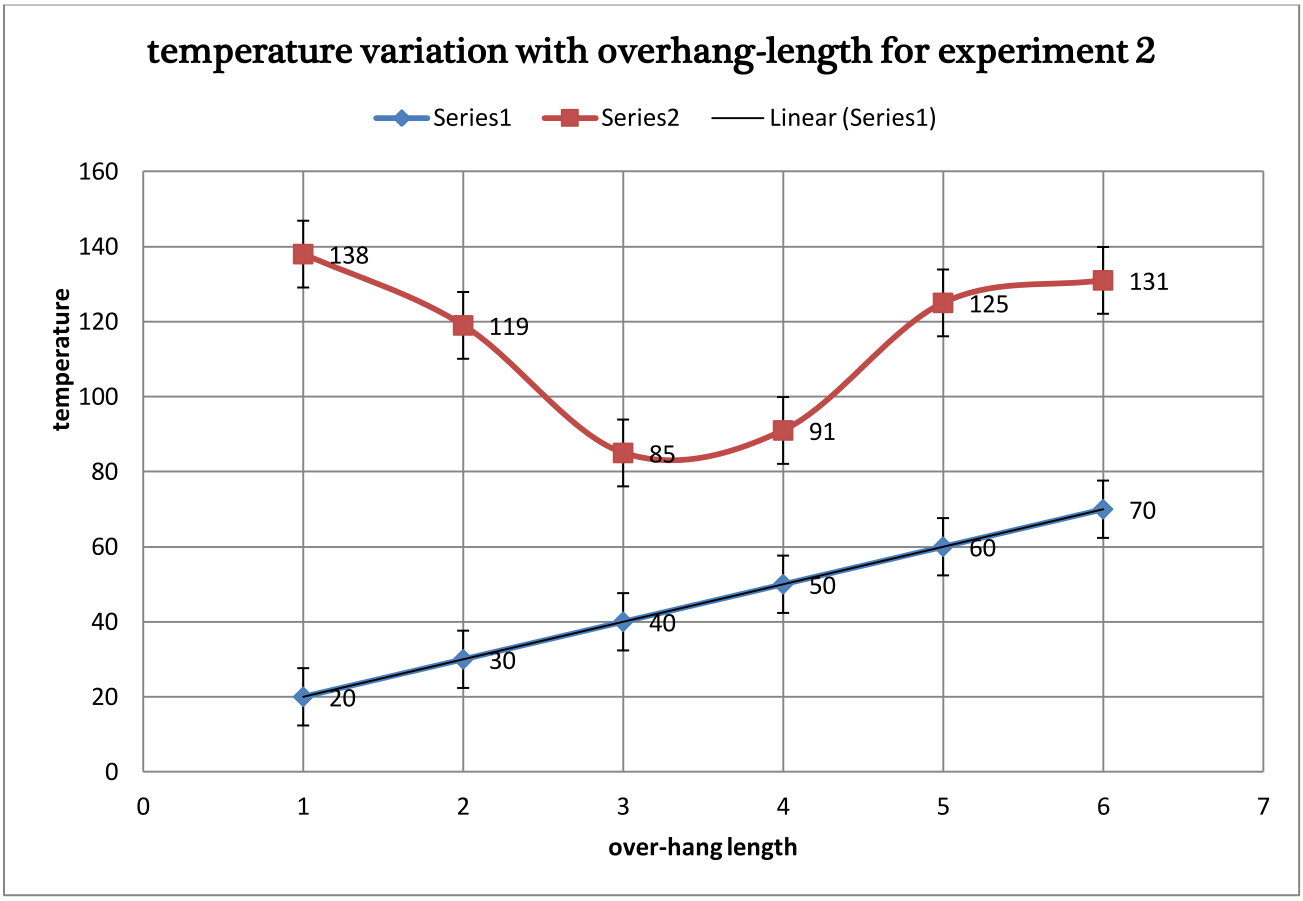
4.1 INTRODUCTION

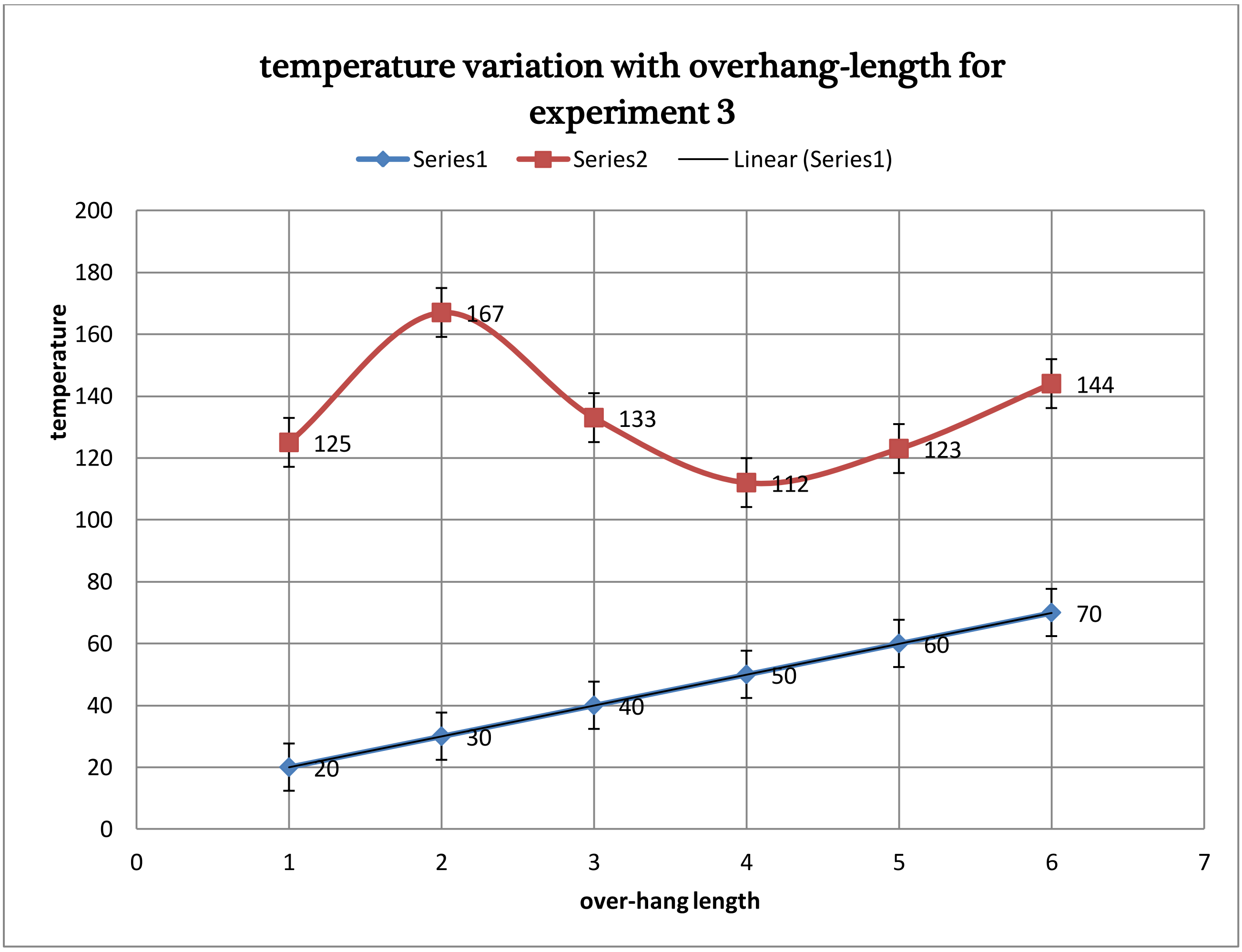
In this chapter, we are going to present our project findings and then analyze and discourse the results. It will include data tables, graphs and photographs showing the results observed. For example, in the case of microscopy in chip morphology study and the chip shape & size in external turning operations. In the next section is the experimental results obtained which will be followed by a brief discussion. These results were obtained based on the following turning parameters.

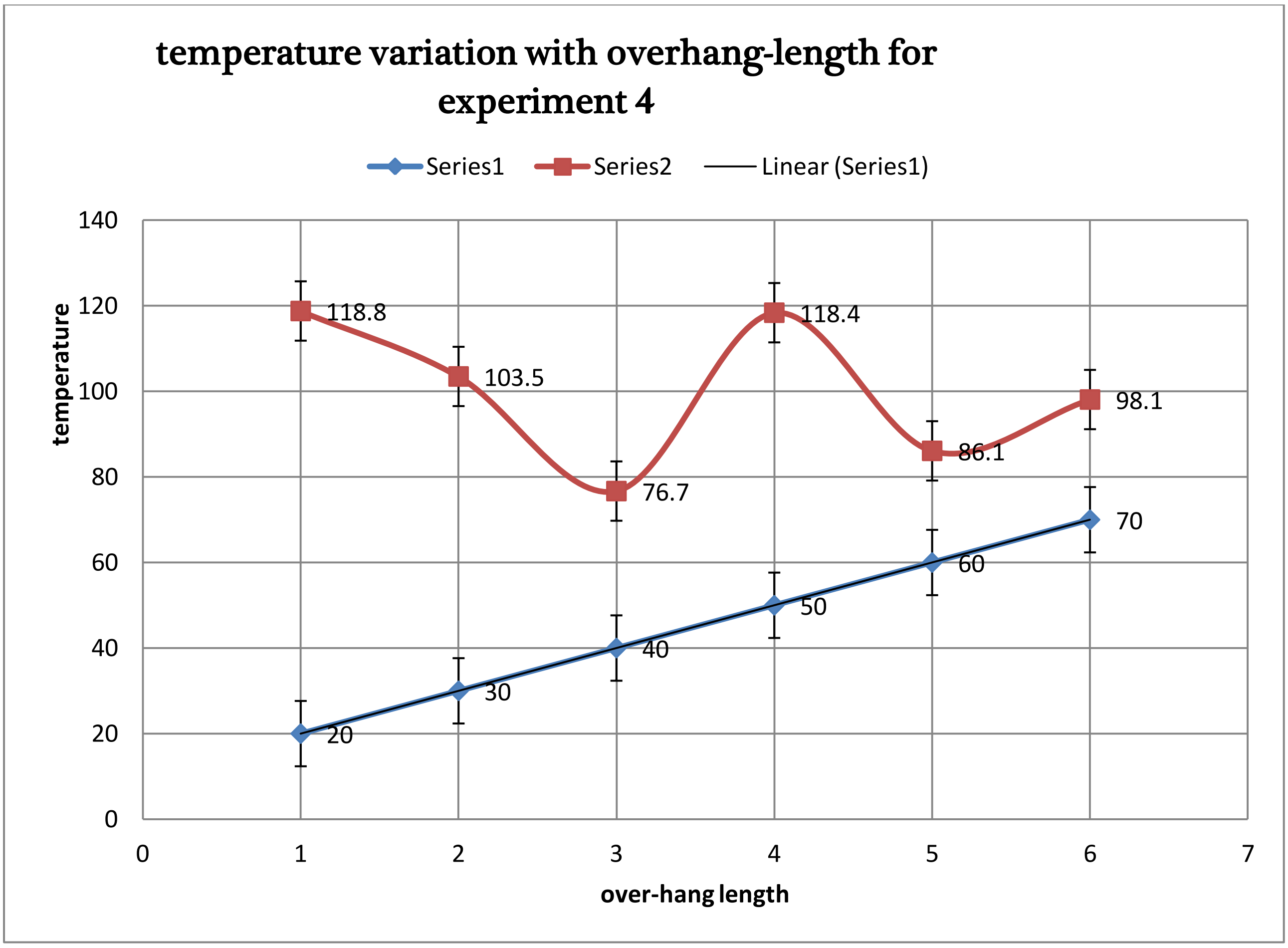
4.2 VARIATION OF TOOL TIP TEMPERATURE WITH OVER-HANG LENGTH.

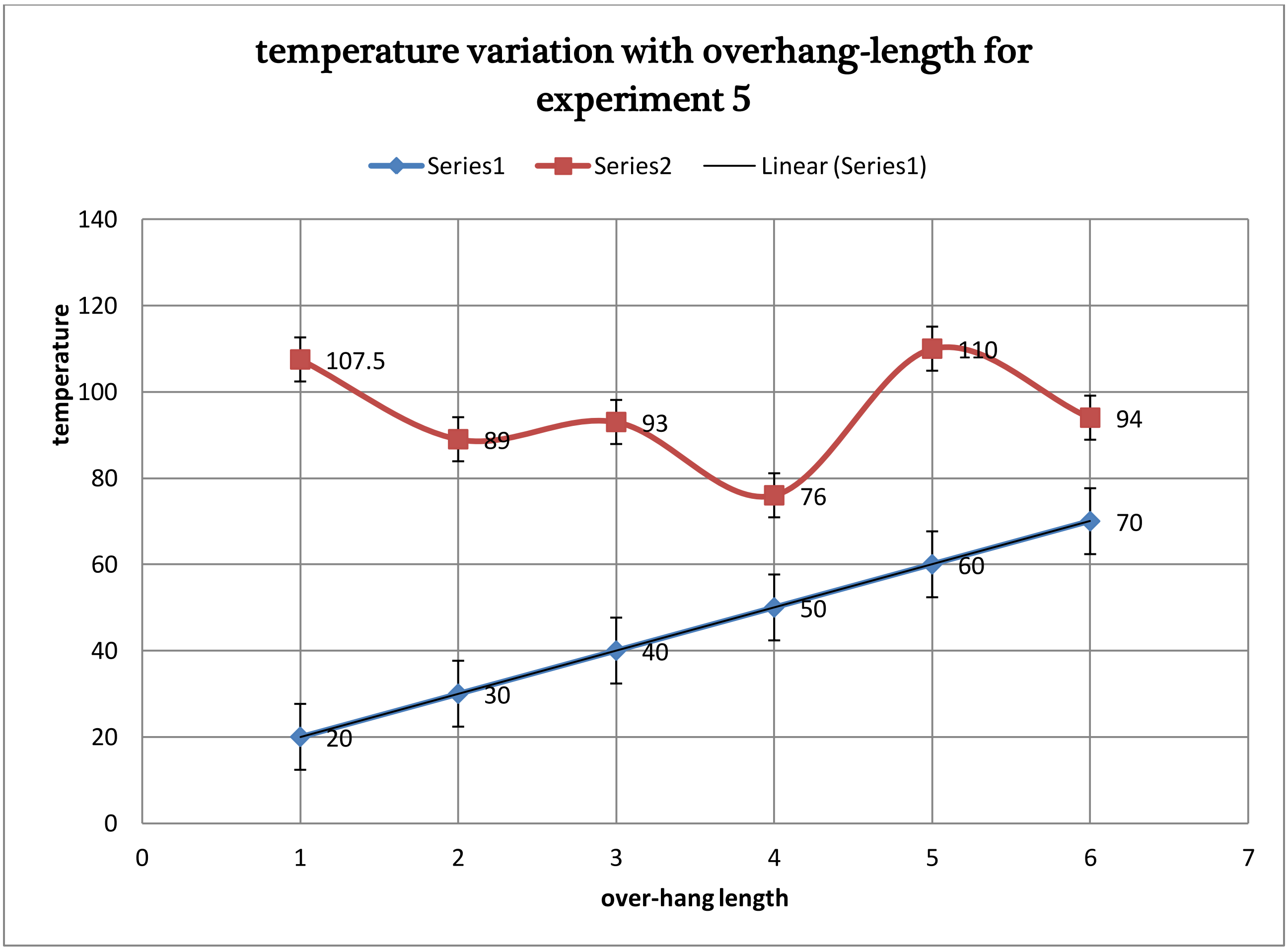
The data tables of the following graphs will be found on the last pages of the report and will be numbered according to the experiments.

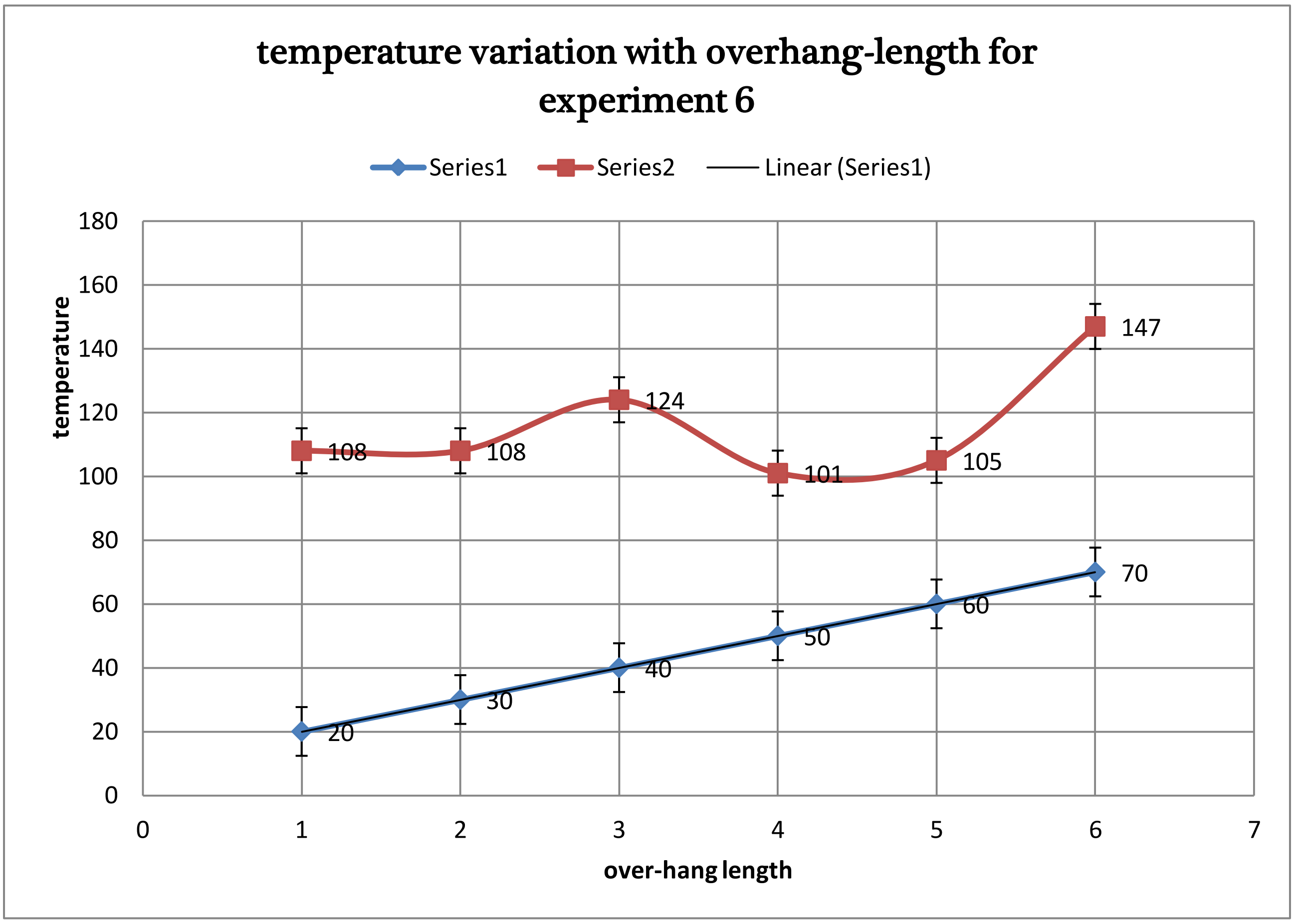


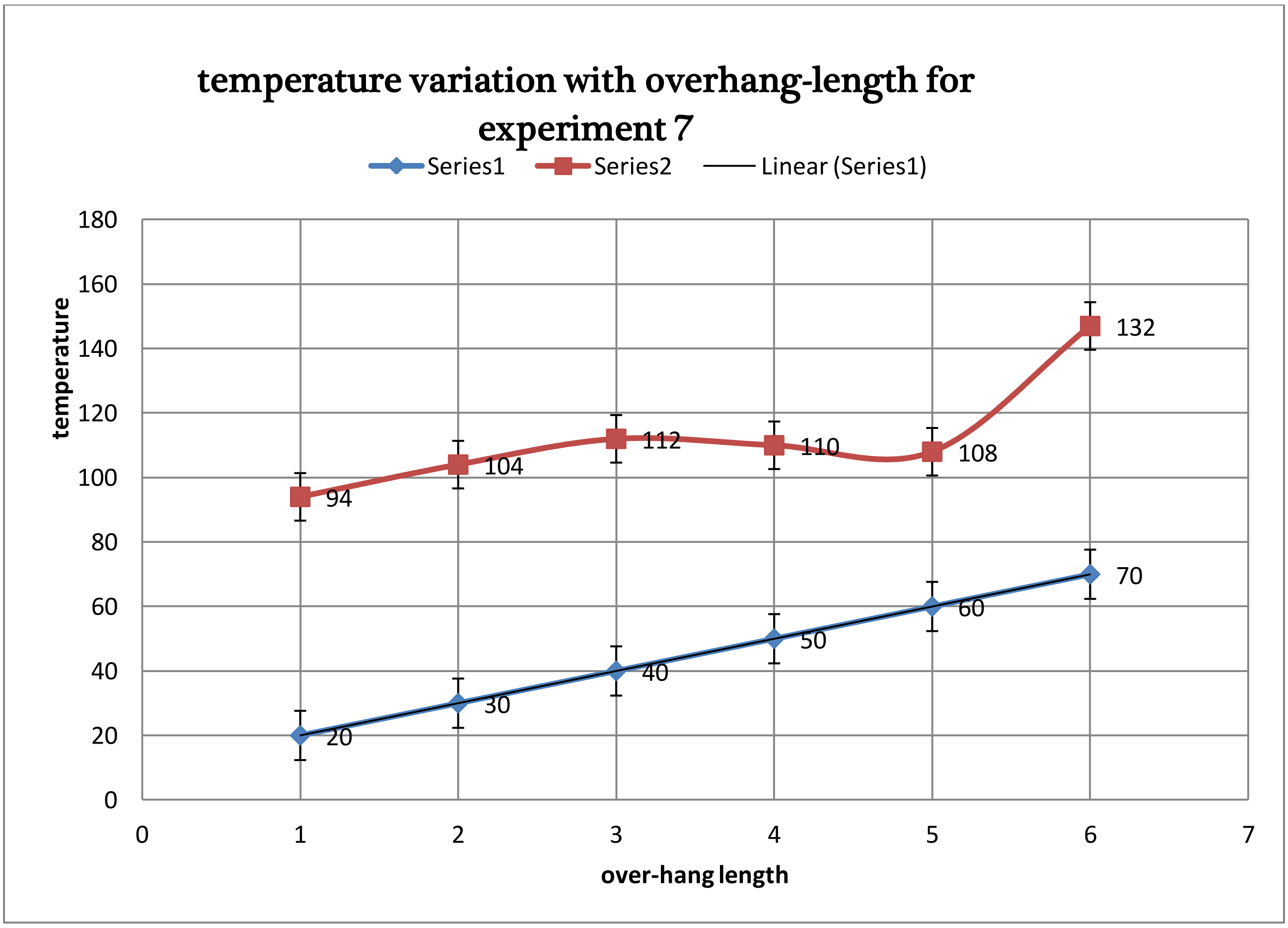

temperature variation with overhang-length for experiment 2
Series1
Series2
Linear (Series1)
temperature
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
over-hang length
138
119
85
91
125
131
20
30
40
50
60
70

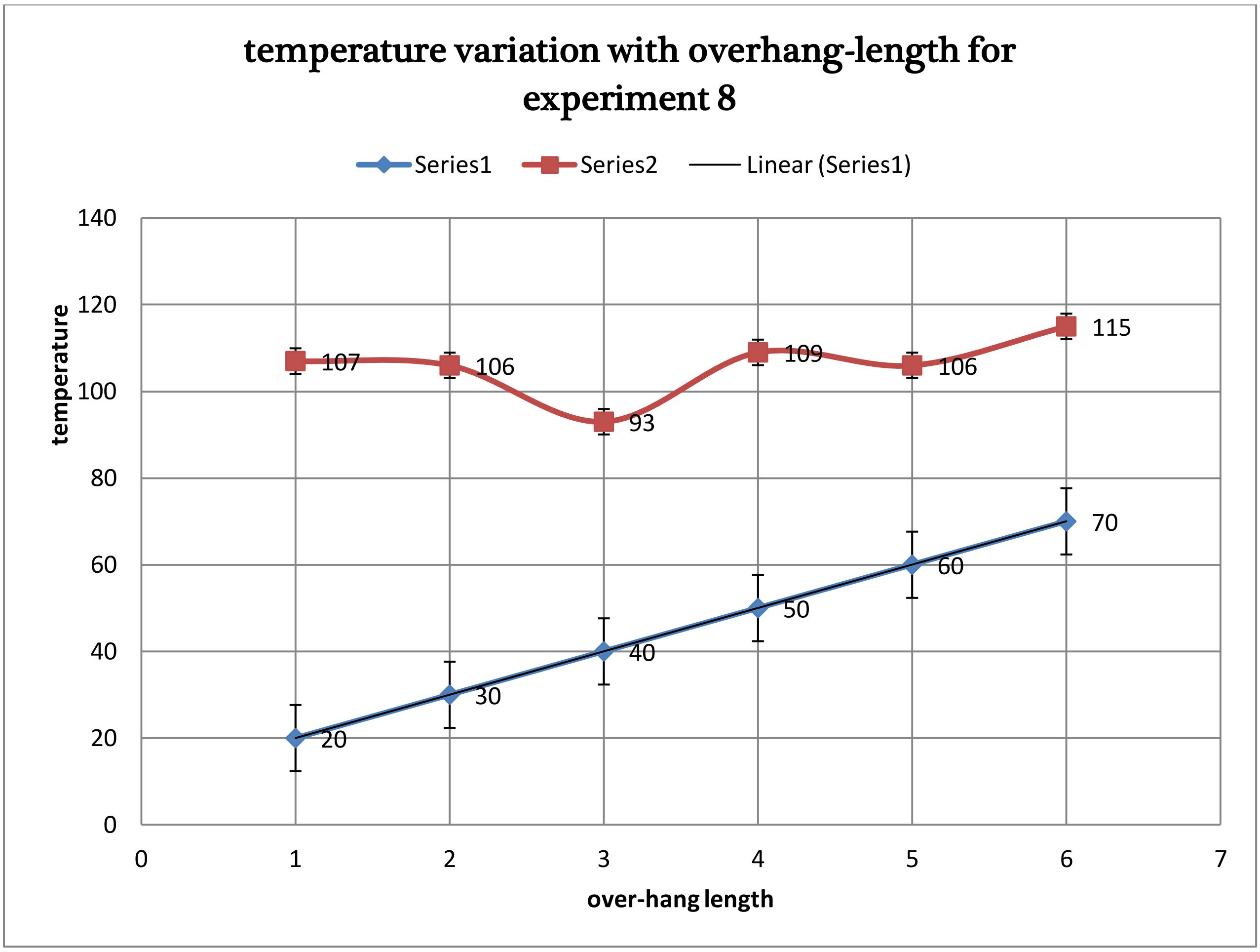

temperature variation with overhang-length for experiment 3
Series1
Series2
Linear (Series1)
temperature
200
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
over-hang length
125
167
133
112
123
144
20
30
40
50
60
70


temperature variation with overhang-length for experiment 4
Series1
Series2
Linear (Series1)
temperature
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
over-hang length
118.8
103.5
76.7
118.4
86.1
98.1
20
30
40
50
60
70


temperature variation with overhang-length for experiment 5
Series1
Series2
Linear (Series1)
temperature
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
over-hang length
107.5
89
93
76
110
94
20
30
40
50
60
70


temperature variation with overhang-length for experiment 6
Series1
Series2
Linear (Series1)
temperature
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
over-hang length
108
108
124
101
105
147
20
30
40
50
60
70


temperature variation with overhang-length for experiment 7
Series1
Series2
Linear (Series1)
temperature
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
over-hang length
94
104
112
110
108
132
20
30
40
50
60
70



4.2.1 GRAPH INFORMATION.

From the graphs, we noticed a marked variation in readings for different diameters. This proves that the effect of job diameter can't be ignored or treated lightly. It also shows that between the over-hang lengths 30 to 60, the tool tip temperature tends to be small. This is advantageous in that it increases the tool life while preventing job deformation due to stress and strain as a result of high temperatures. Therefore one can say the best over hang length falls within the range 30 to 60 for the given job piece with slight variation in diameter per experiment.

4.2.2 POSSIBLE SOURCES OF ERROR.

Despite the care we took, there might still have been possible errors caused by;

- Workshop ventilation system, affecting the temperature reading.
- Natural variation in ambient conditions e.g., humidity, room temperature. Etc.
- Loose contact of thermocouple could give wrong readings.
- Electric fans running in the course of the experiment.

- Improper connections of the temperature measuring device.
- Power failures during the experiment.
- None uniform density of the material.
- Internal cracks developed during condensing (when the metal rod was manufactured.)

However we tried to limit any scope for error as much as possible making the results more reliable.

4.2.3 EFFECT OF VARIATION OF DIAMETER FOR THE SAME OVERHANG LENGTH.

- Reduction in diameter causes a considerable drop in temperature. WHY?

For the same over-hang length, change in diameter affected the temperature reading. In our opinion, the surface area of contact between the tool cutting point and the job might have been the reason behind the drop in tool tip temperature when we reduced the diameter. This is shown on the table below.

OVER-HANG LENGTH	**JOB DIAMETER**	**TOOL-TIP TEMPERATURE**
30	**31**	**167**
30	**23**	**90.01**

Table: effect of change in job diameter for same over-hang length.

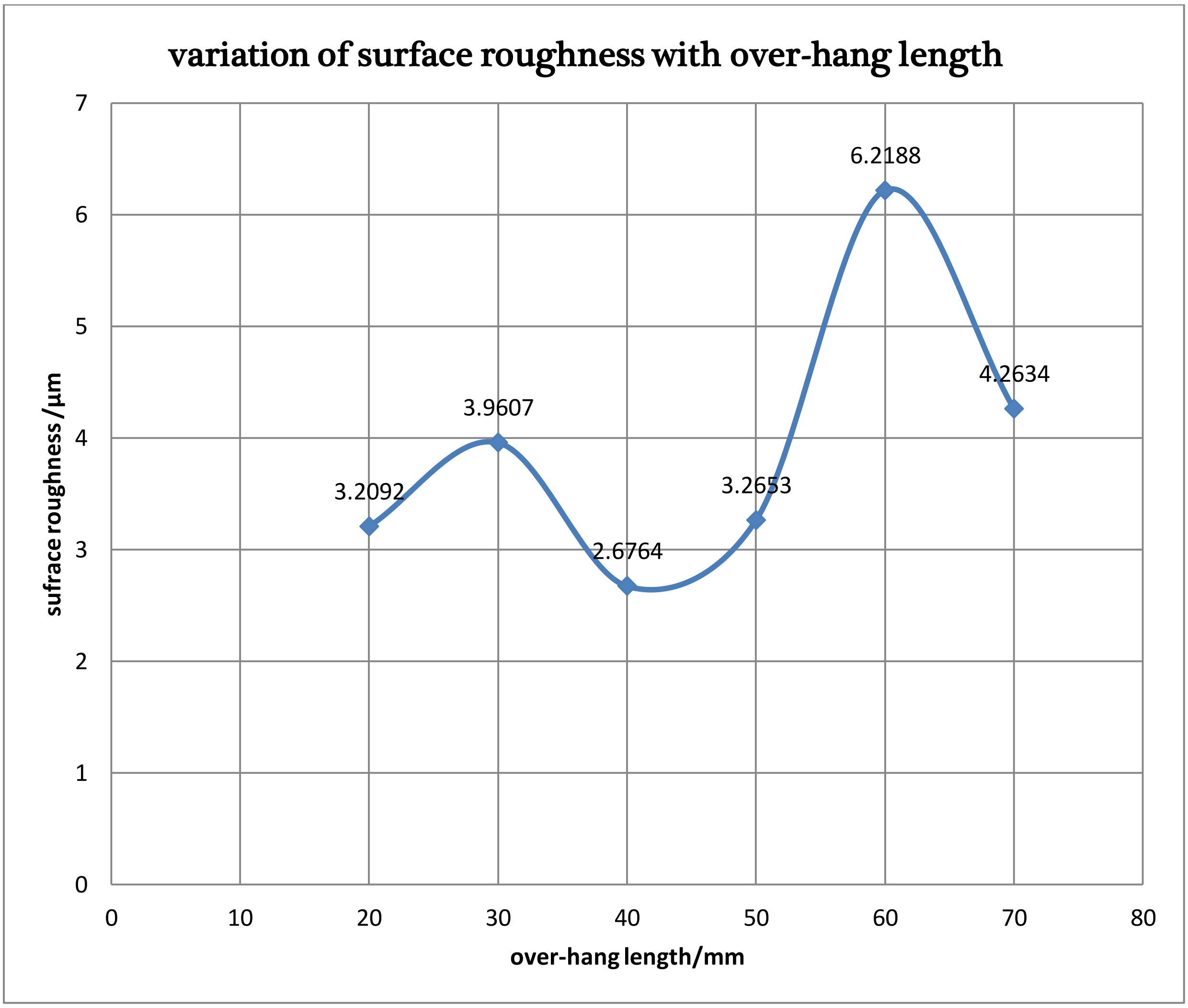
This was a clear indication that we must use the same job diameter for all the job pieces per experiment. The observed results were satisfactory.

4.3 VARIATION OF SURFACE ROUGHNESS WITH OVER-HANG LENGTH.

In determining the surface roughness, several experiments were performed on each job specimen and the average reading taken. This was our way of limiting error due to non-uniformity on the surface roughness of the job. The tables will be found on the last pages of the report. Below is the graph showing the variation.

4.3.1 GRAPH INFORMATION.

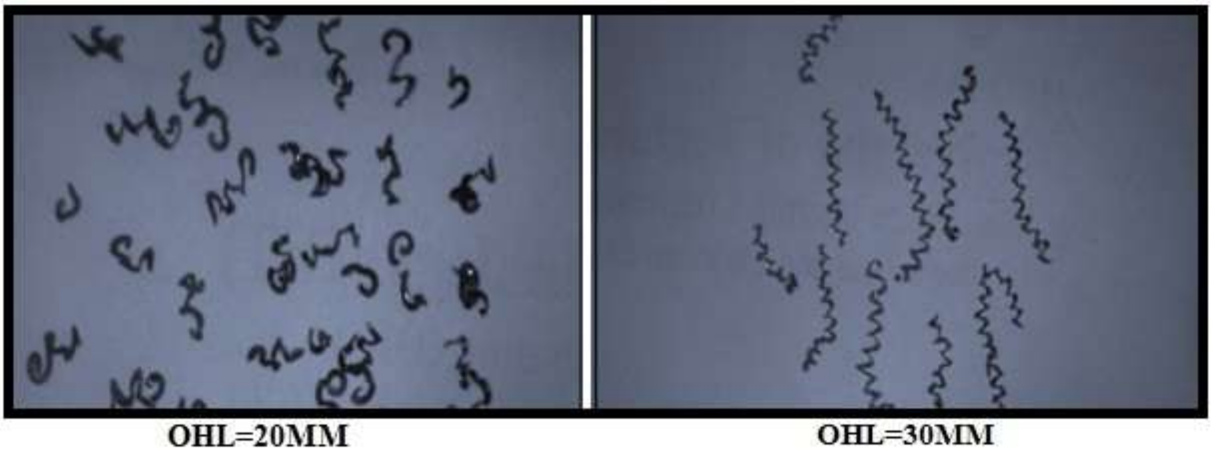
From the graph, it is seen that the lowest roughness value (direct implication of the best quality) falls between the over-hang lengths 40 and 50 more or less. This implies that for the job diameter used the best over-hang length for better quality lies within the range 35mm to 55mm. This range is to compensate for the effect of change in diameter within the same limits.



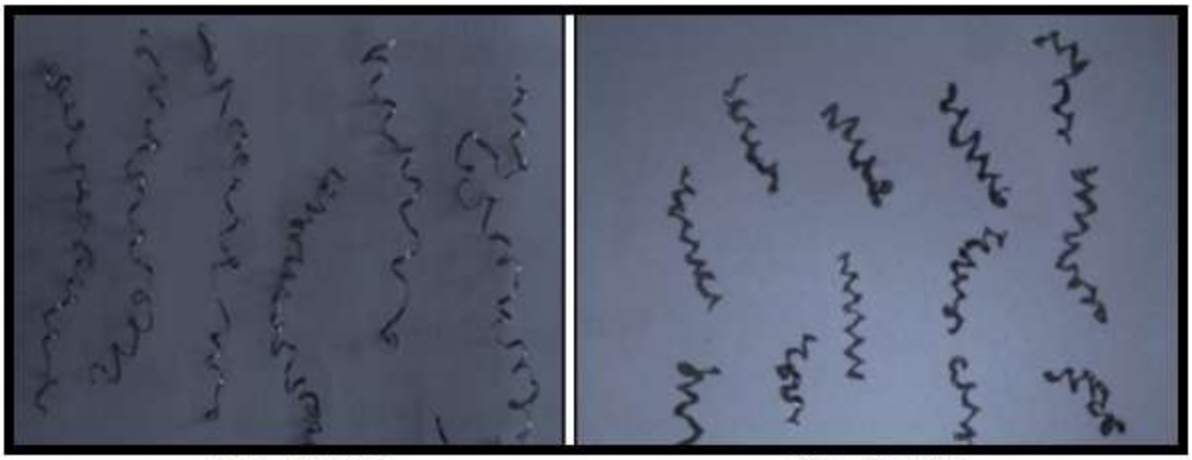
Graph: variation of surface roughness against over-hang length.

4.4 VARIATION OF CHIP STRUCTURE WITH CHANGE IN OVER-HANG LENGTH.

After turning, we took a sample of some of the chips per experiments and observed. The following results were obtained.



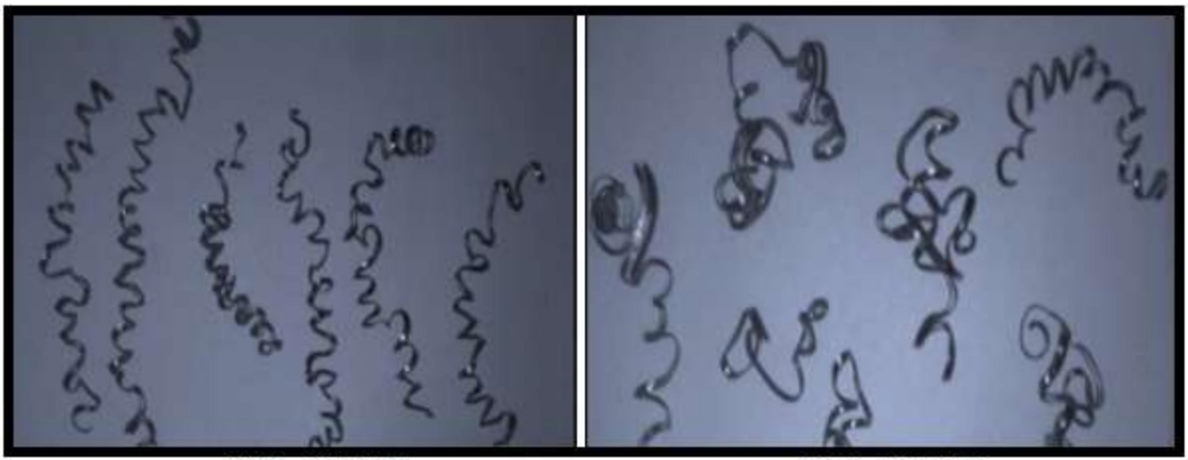
16Fig 4.4a Chip structure for over-hang length 20mm and 30mm



OHL=40MM OHL=50MM

17Fig 4.4b Chip structure for over-hang length 40mm and 50mm

.



OHL=60MM OHL=70MM

18Fig 4.4c Chip structure for over-hang length 60mm and 70mm

4.4.1 INFORMATION FROM THE RESULTS.

From the figures, one can see that there is marked variation in the structure, shape and sizes of the chips obtained per over-hang length. This is attributed to the fact that some over-hang lengths are more favorable to production that some. From the photos, we observed that:

- The chips for overhang-length 20mm, uncoiled and highly discontinuous.
- Chips from tool over-hangs 30 and 50 had similar structures but different sizes. The chips for tool over hang length 50 appeared a little bigger in size.
- Chips from tool over-hangs 40 and 60 had slightly similar structures; however, the sizes seemed different. The chips also looked disorderly curly perhaps due to the stress developed

during formation as a result of overheating. This can also be checked from the graphs for appropriateness.

- The chips from the tool over-hang length 70mm appeared highly disorganized and not curly. This most have resulted from the vigorous acoustic and mechanical vibrations developed in the tool during operation, leading to high temperatures at the tool tip which led to high internal stress.

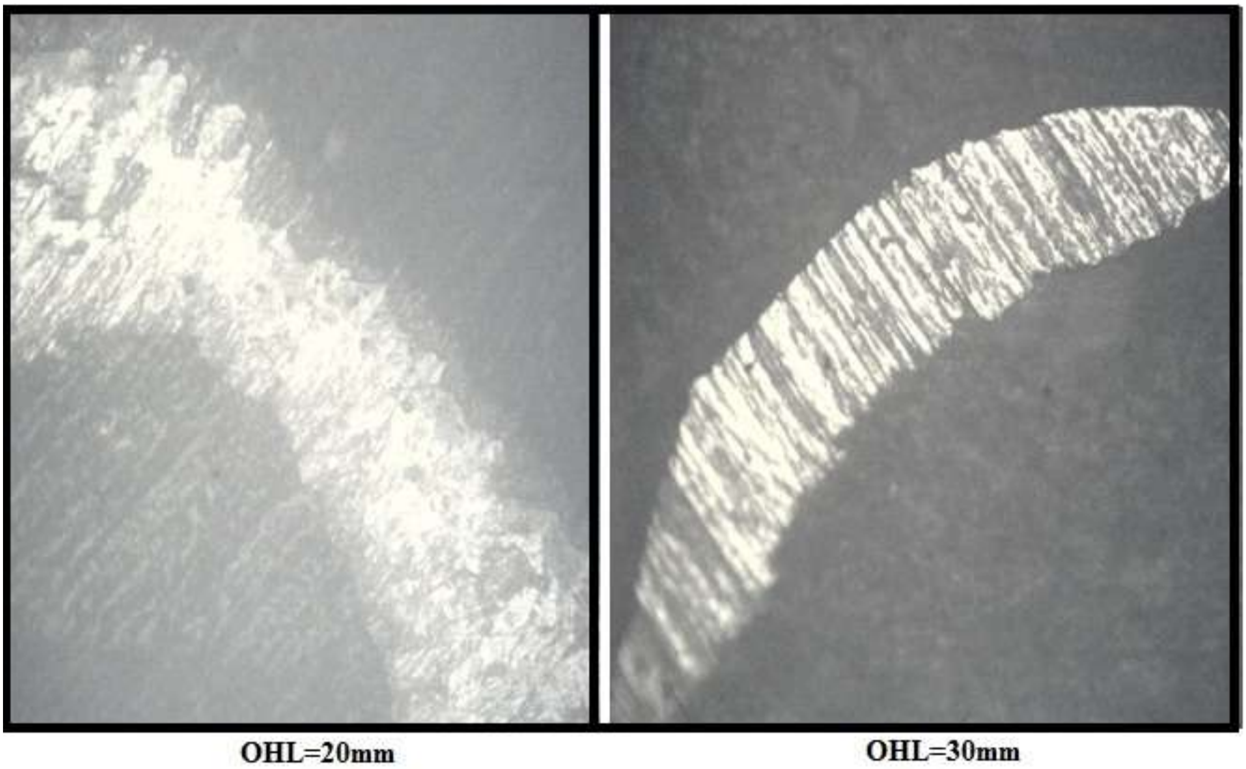
4.4.2 OTHER OBSERVATIONS.

We observed that some of the chips formed for higher tool over-hang lengths were discontinues just like for the over-hang length 20mm. further analysis of the job pieces revealed that some of the work pieces had internal cracks in them. We suggested they might have been formed in the process of cooling (accidental rapid cooling) during manufacturing.

We also observed that the tool geometry had an effect on the shape, size and thickness of the chips produced; as a result, we made sure the tool geometry was about the same for all the experiments to increase the reliability of our findings.

4.5 Variation of chip grain structure with change in tool over-hang length.

In this section, we are going to present the chip grain structures are observed under the microscope under the magnification 10X. Below are the microscopic imageries for each of the job pieces with the respective tool over-hang lengths.


OHL=20mm

OHL=30mm

19Fig 4.5a Microscopic observation of the chip morphology. (OHL: over-hang length.)

OHL=40mm **OHL=50mm**

20Fig 4.5b Microscopic observation of the chip morphology. (OHL: over-hang length.)

OHL=60mm **OHL=70mm**

21Fig 4.5c Microscopic observation of the chip morphology. (OHL: over-hang length.)

4.5.1 ACCOUNT ON NATURE OF CHIP MORPHOLOGY OBSERVED

i) Influence of over-hang length on the chip morphology

The chip formation mechanism depends on the variation of several cutting parameters and particularly cutting speed. This is however not the case of hard turning. Indeed, the micrographs in Fig. 3 show that cutting speed has no influence on the general morphology of the chip. Indeed, for varying cutting speeds from 50 to 250 m/min and an advance of (0.1 mm/rev), all chips are have a "saw tooth" shape. This morphology is often observed in the case of the machining of hard steels of low thermal conductivity. The low thermal conductivity and the rapid dissipation of energy lead us to con-sider the shear zone as an area of adiabatic shear. These chips are formed by a localization of deformation and catastrophic shear resulting from the increase in hardness and brittleness of the material. Thus, the mechanism of the generation of these chips is based on the initiation of a crack followed by a slip.

However, the change of the mechanism of chip formation is associated with the appearance of the shear instability. This instability originates from a competition between thermal softening and dynamic hardening of the machined material. This mechanism can be expressed by laws of the material behavior that takes into account the sensitivity to the strain rate, the strain hardening, and the thermal softening.

The requirements of the work material beyond the elastic limits are accompanied by an elevation in temperature within the workpiece. The higher the strain rate, the more elevated the temperature. Therefore, work-hardening and thermal-softening phenomena result in an elevation of the temperature.

With an increase in the overhang length, the shearing bands become more and more intense, with a considerable reduction in the width of contact between the segments up to fragmentation. This is attributed to the phenomenon of localized deformation in the primary shear zone, which becomes more important with the increase in the temperature.

Indeed, in the study of the relationship between cutting temperature and speed, it is shown that the temperature is higher for higher speeds. The mechanical properties of material thus decrease in the cutting zone, which reduces resistance to the plastic deformation and thus causes an abrupt shearing of the chip by creating a plastic instability. It should be noted that for a feed rate of 0.1 mm/rev, the appearance frequency of the chips often increases as the over-hang length increases.

ii) Influence of feed rate on the morphology of the chip

The analysis of the chips shows that the feed rate in turn considerably influences the morphology of the chips. Certainly, the machining of steel with small feed rates (f = 0.02 mm/rev) enables us to obtain a continuous chip. This chip is due to quasi-stationary plastic deformation in the zones of shearing. However, with an increase in the feed rate and at a constant cutting speed (rpm = 530 r/min), the chip is increasingly scalloped (i.e., it takes on more and more the shape of the saw-tooth chip due to cyclic cracking).

The results obtained in this study for chip morphology and the change in shape of the steel chips according to cutting conditions are similar to the results found by Poulachon- a researcher in a similar field. This proves that the mode of chip formation for hardened steel is same. Same phenomena such as segmentation, thermal softening, cracking etc., are the result of the microstructural change in the martensitic structure. A thicker white layer indicates severe thermal dam-age. The formation of this white layer occurs because of the very rapid localization of intensive mechanical and thermal energies in a strict zone, which causes the metallurgical trans-formation and naturally gives the white area.

4.6 DISCUSSION

For recent industrial development and continuous progress, it is essential to determine a way to increase speed and feed rate to further increase productivity. But increasing speed and feed rates lead to problems such as tool wear, tool life reduction, and reduced surface quality among other problems. As a result, it is necessary to develop a new system which fulfills this requirement with fewer criticisms. From recent technologies, High Pressure Cooling Jet has shown a performance up to the desirable standard.

In this experiment, we analyzed chip morphology to determine the suitability of over-hang length with coated carbide inserts. It is recommended that more experiments should take place to see the effect of tool overhang length on Tool life and surface roughness with coated carbide inserts.

CHAPTER 5

RECOMMENDATION FOR FUTURE WORK

5.1 INTRODUCTION

The work that has been presented in this licentiate work is a preliminary study of the research problem. This thesis work will continue and further improvements are planned in future work. Our areas of concern for future works include;

a) Improving the robust design for optimization of dynamic stiffness of tool holders
b) Improving the carbon nano composite material's Young's modulus and Damping
c) Enhancing surface roughness.
d) Decreasing tool tip wear.

5.2 IMPROVING THE ROBUST DESIGN FOR OPTIMIZATION OF DYNAMIC STIFFNESS OF TOOL HOLDERS

The experimental results on surface roughness indicate that an optimization of the mechanical structures' dynamic stiffness is necessary while designing for robust property against vibration problem. One of the approaches is to have a rigid tool holder that can keep the clamping pressure at the optimized value. Problems might occur concerning the tool holders' durability and accuracy, while in an operating condition, when the clamping pressure in the interface is too low. One design target for mechanical structures and machines is to enhance the controllability of the designed object. If the optimization of the tool holders' normal pressure can be designed in such a way that the durability of the joints can be predictable, then it is worth making tool holders with higher dynamic stiffness, while partially losing static stiffness.

5.3 IMPROVING THE CARBON NANO COMPOSITE MATERIAL'S YOUNG'S MODULUS AND DAMPING

As the main contribution to a material's damping property is from the interface between the different phases in various domains, the approach to enhance the damping is to maximize the internal surface to volume ratio in the created material. Through adjusting the process parameters, the grain size of the carbon nano particles can be changed. The matrix material that controls the Young's modulus of the material can come from various sources, and the best option would be to make it with diamond carbon. Process parameters, such as the feed, machine rpm, depth of cut, room temperature, and so on, will change to optimize the material's Young's modulus and damping property.

5.4 ENHANCING SURFACE ROUGHNESS

Surface finishes of jobs are of great importance in the manufacturing industries as they give an implication of the job quality. Further studies on how to make the surface finish of great quality and smoothness, with little or no thermal deformation should be undertaken.

5.5 DECREASING TOOL TIP WEAR

Based on our observations during the study, we noticed that worn tool tips affected the surface finish of the jobs adversely. As a result, we propose that further studies should be undertaken here to optimize the effectiveness of the tool while preventing tool tip wear.

This would be done by further selecting standard machining parameters through experiments and the analysis of the results.

CHAPTER 6

REFERENCES AND LIST OF TABLES

6.1 REFERENCES:

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6.2 LIST OF TABLES

Surface roughness for over-hang length 20

Point Num	Reading .1	Reading 2	Reading 3	Reading 4	Reading 5	Average Reading
P1	3.196	3.214	3.193	3.181	3.182	3.1932
P2	3.346	3.351	3.336	3.329	3.321	3.3366
P3	3.111	3.111	3.122	3.116	3.080	3.108
P4	3.205	3.194	3.195	3.199	3.201	3.1988
L_{av1} =3.2092µm						

Surface roughness for over-hang length 30

Point Num	Reading .1	Reading 2	Reading 3	Reading 4	Reading 5	Average Reading
P1	3.766	3.745	3.740	3.753	3.784	3.7576
P2	3.829	3.825	3.850	3.821	3.819	3.8288
P3	3.161	3.162	3.605	3.616	3.603	3.4294
P4	4.846	4.813	4.792	4.837	4.846	4.8268
L_{av2} =3.9607µm						

Surface roughness for over-hang length 40

Point Num	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Average Reading
P1	2.114	2.124	2.117	2.125	2.141	2.1242
P2	2.444	2.437	2.427	2.434	2.410	2.4304
P3	3.072	3.067	3.096	3.085	3.093	3.0826
P4	3.064	3.065	3.076	3.064	3.072	3.0682
L_{av3} =2.6764µm						

Surface roughness for over-hang length 70

Point Num	**Reading 1**	**Reading 2**	**Reading 3**	**Reading 4**	**Reading 5**	**Average Reading**
P1	4.381	4.352	4.422	4.328	4.347	4.1534
P2	4.215	4.311	4.235	4.229	4.237	4.2454
P3	4.459	4.249	4.226	4.195	4.159	4.2576
P4	4.428	4.392	4.438	4.364	4.364	4.3972
L_{av6} =4.2634µm						

Table: Over-hang length Vs Average Surface roughness

observation	**Over-hang length**	**Average Surface roughness**
1	20	3.2092
2	30	3.9607
3	40	2.6964
4	50	3.2653
5	60	6.2188
6	70	4.2634

Experiment 1

observation	overhang length in mm	tool-tip temperature in °C
1	20	80
2	30	78
3	40	93
4	50	79
5	60	98
6	70	105

Experiment 2

observation	overhang length in mm	tool-tip temperature in °C
1	20	138
2	30	119
3	40	85
4	50	91
5	60	125
6	70	131

Experiment 3

observation	overhang length in mm	tool-tip temperature in ℃
1	20	125
2	30	167
3	40	133
4	50	112
5	60	123
6	70	----

Experiment 4

observation	overhang length in mm	tool-tip temperature in ℃
1	20	118.8
2	30	103.5
3	40	76.7
4	50	118.4
5	60	86.1
6	70	98.1

Experiment 5

observation	overhang length in mm	tool-tip temperature in ℃
1	20	107.9
2	30	89
3	40	93
4	50	76
5	60	110
6	70	94

Experiment 6

observation	overhang length in mm	tool-tip temperature in ℃
1	20	108
2	30	108
3	40	124
4	50	101
5	60	105
6	70	147

Experiment 7

observation	overhang length in mm	tool-tip temperature in ℃
1	20	94
2	30	104
3	40	112
4	50	110
5	60	108
6	70	132

Experiment 8

observation	overhang length in mm	tool-tip temperature in ℃
1	20	107
2	30	106
3	40	93
4	50	109
5	60	106
6	70	115

Surface roughness for over-hang length 40

Point Num	**Reading 1**	**Reading 2**	**Reading 3**	**Reading 4**	**Reading 5**	**Average Reading**
P1	2.114	2.124	2.117	2.125	2.141	2.1242
P2	2.444	2.437	2.427	2.434	2.410	2.4304
P3	3.072	3.067	3.096	3.085	3.093	3.0826
P4	3.064	3.065	3.076	3.064	3.072	3.0682
L_{av3} =2.6764µm						

Surface roughness for over-hang length 50

Point Num	**Reading 1**	**Reading 2**	**Reading 3**	**Reading 4**	**Reading 5**	**Average Reading**
P1	3.133	3.141	3.157	3.149	3.146	3.1452
P2	3.508	3.517	3.515	3.512	3.502	3.5108
P3	2.996	3.000	3.006	3.054	2.992	3.0096
P4	3.441	3.445	3.440	3.451	3.201	3.3956
L_{av4} =3.2653µm						

Surface roughness for over-hang length 60

Point Num	**Reading 1**	**Reading 2**	**Reading 3**	**Reading 4**	**Reading 5**	**Average Reading**
P1	6.165	6.050	6.066	6.036	6.049	6.0732
P2	6.147	6.146	6.118	6.135	6.136	6.1364
P3	6.511	6.640	6.454	6.433	6.425	6.4926
P4	6.164	6.192	6.209	6.145	6.145	6.1728
L_{av5} =6.2188µm						